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Since A. D. 1500 as Identified by Well-Dated Tree Rings
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Applied Research Reconstructing Past Climate
of the Northern Hemisphere by Use of Tree Rings
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TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>LIST OF ILLUSTRATIONS</th>
<th>iii</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIST OF TABLES</td>
<td>iv</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>v</td>
</tr>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>II. CLIMATIC VARIATIONS FOR NORTH AMERICA AND THE NORTH PACIFIC SINCE A.D. 1500 AS IDENTIFIED BY WELL-DATED TREE RINGS (NSF Grant No. ATM75-22378)</td>
<td>5</td>
</tr>
<tr>
<td>A. The Transfer Function (Blasing and Carter)</td>
<td>6</td>
</tr>
<tr>
<td>B. Model Construction (Blasing and Fritts)</td>
<td>9</td>
</tr>
<tr>
<td>C. Model Evaluations (Blasing, Fritts, and Winter)</td>
<td>13</td>
</tr>
<tr>
<td>D. Independent Verification (Lofgren, Ares, and Fritts)</td>
<td>18</td>
</tr>
<tr>
<td>E. Data Retrieval and Analysis</td>
<td>21</td>
</tr>
<tr>
<td>III. APPLIED RESEARCH RECONSTRUCTING PAST CLIMATE OF THE NORTHERN HEMISPHERE BY USE OF TREE RINGS (NSF Grant No. ATM75-17034)</td>
<td>31</td>
</tr>
<tr>
<td>A. Status of Tree-Ring Collections and Mergers (DeWitt and Wiseman)</td>
<td>31</td>
</tr>
<tr>
<td>B. International Tree-Ring Data Bank (Sherwood)</td>
<td>38</td>
</tr>
<tr>
<td>C. Laboratory of Tree-Ring Research Data Base (Robinson)</td>
<td>44</td>
</tr>
<tr>
<td>D. Experiments with Different Tree-Ring and Climatic Grids (Conkey)</td>
<td>45</td>
</tr>
<tr>
<td>E. New England Climatic Reconstruction (Conkey)</td>
<td>50</td>
</tr>
<tr>
<td>F. Continuing Experiments in Reconstructing Crop Yields (Blasing)</td>
<td>51</td>
</tr>
<tr>
<td>G. Climatic Typing (Lofgren)</td>
<td>55</td>
</tr>
<tr>
<td>H. Assessing the Value of Densitometric Data from Swiss Alpine Trees (Fritts)</td>
<td>62</td>
</tr>
<tr>
<td>I. Ring-Width Standardization Procedures (Fritts, Winter, and Lofgren)</td>
<td>63</td>
</tr>
<tr>
<td>J. Travel</td>
<td>64</td>
</tr>
<tr>
<td>IV. SUMMARY AND SIGNIFICANCE OF THIS WORK</td>
<td>67</td>
</tr>
<tr>
<td>A. Summary of Most Significant Results on NSF Grant No. ATM75-17034 (Applied Research Reconstructing Past Climate of the Northern Hemisphere by Use of Tree Rings)</td>
<td>67</td>
</tr>
<tr>
<td>B. Summary of Most Significant Results on NSF Grant No. ATM75-22378 (Climatic Variations for North America and the North Pacific Since A.D. 1500 as Identified by Well-Dated Tree Rings)</td>
<td>69</td>
</tr>
<tr>
<td>C. An Illustrative Study of a Particular Climatic Variation: The Winter of 1976-77</td>
<td>70</td>
</tr>
<tr>
<td>V. PERSONNEL WORKING ON GRANT FUNDS</td>
<td>86</td>
</tr>
<tr>
<td>Section</td>
<td>Title</td>
</tr>
<tr>
<td>---------</td>
<td>-------</td>
</tr>
<tr>
<td>VI.</td>
<td>PUBLICATIONS RESULTING FROM THIS GRANT</td>
</tr>
<tr>
<td>VII.</td>
<td>PAPERS IN PREPARATION</td>
</tr>
<tr>
<td>VIII.</td>
<td>LITERATURE CITED</td>
</tr>
<tr>
<td>IX.</td>
<td>PROPOSAL</td>
</tr>
<tr>
<td></td>
<td>A. Introduction</td>
</tr>
<tr>
<td></td>
<td>B. Tasks</td>
</tr>
<tr>
<td></td>
<td>C. Workshops</td>
</tr>
<tr>
<td></td>
<td>D. Organization and Personnel</td>
</tr>
<tr>
<td></td>
<td>E. Competence</td>
</tr>
<tr>
<td></td>
<td>F. Travel</td>
</tr>
<tr>
<td></td>
<td>G. Time Schedule</td>
</tr>
<tr>
<td>X.</td>
<td>OTHER GRANT SUPPORT</td>
</tr>
<tr>
<td>XI.</td>
<td>VITAE</td>
</tr>
<tr>
<td>XII.</td>
<td>BUDGET</td>
</tr>
<tr>
<td></td>
<td>APPENDIX 1: International Tree-Ring Data Bank Newsletter</td>
</tr>
<tr>
<td></td>
<td>APPENDIX 2: Press Release</td>
</tr>
</tbody>
</table>
# LIST OF ILLUSTRATIONS

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>The anomaly in tree growth from 1601-1900 for the 65 selected tree-ring chronologies used in calibration</td>
<td>24</td>
</tr>
<tr>
<td>2.</td>
<td>Winter pressure anomaly Type 1 and the corresponding anomalies in temperature and precipitation</td>
<td>56</td>
</tr>
<tr>
<td>3.</td>
<td>Winter pressure anomaly Type 2 and the corresponding anomalies in temperature and precipitation</td>
<td>57</td>
</tr>
<tr>
<td>4.</td>
<td>Winter pressure anomaly Type 3 and the corresponding anomalies in temperature and precipitation</td>
<td>58</td>
</tr>
<tr>
<td>5.</td>
<td>Winter pressure anomaly Type 4 and the corresponding anomalies in temperature and precipitation</td>
<td>59</td>
</tr>
<tr>
<td>6.</td>
<td>Winter pressure anomaly Type 5 and the corresponding anomalies in temperature and precipitation</td>
<td>60</td>
</tr>
<tr>
<td>7.</td>
<td>Time series plots for actual and average reconstructed winter temperature at eight stations in California</td>
<td>71</td>
</tr>
<tr>
<td>8.</td>
<td>Occurrences of winter types for the last four centuries as reconstructed from the 15i15m model</td>
<td>73</td>
</tr>
<tr>
<td>9.</td>
<td>Average winter temperature reconstructed for 1601-1900</td>
<td>76</td>
</tr>
<tr>
<td>10.</td>
<td>Average winter precipitation reconstructed for 1601-1900</td>
<td>77</td>
</tr>
<tr>
<td>11.</td>
<td>Average winter temperature reconstructed for 1601-1650</td>
<td>78</td>
</tr>
<tr>
<td>12.</td>
<td>Average winter precipitation reconstructed for 1601-1650</td>
<td>79</td>
</tr>
<tr>
<td>13.</td>
<td>Average pressure anomalies reconstructed for 1601-1900</td>
<td>80</td>
</tr>
<tr>
<td>14.</td>
<td>Average pressure anomalies reconstructed for 1601-1650</td>
<td>81</td>
</tr>
</tbody>
</table>
LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Summary of Models Calibrated</td>
<td>11</td>
</tr>
<tr>
<td>II. Calibration and Verification Statistics for Six Winter Temperature Models</td>
<td>20</td>
</tr>
<tr>
<td>III. Chronology Status Revisions Made During the Period of This Grant</td>
<td>32</td>
</tr>
<tr>
<td>IV. North American Sites Contributed to the International Tree-Ring Data Bank</td>
<td>41</td>
</tr>
<tr>
<td>V. Results of Crop Yield Reconstructions</td>
<td>53</td>
</tr>
<tr>
<td>VI. Summary of Percentages of Occurrence of Types and Combinations of Types Using Reconstructions from Two Calibration Models for 1601-1899 and Actual Climatic Data for 1900-1970</td>
<td>74</td>
</tr>
<tr>
<td>VII. Frequency of Occurrence of Seasonal Types Preceding and Following a Winter Type 5 (Winter of 1976-1977) Based on Nine Occurrences in Twentieth Century Data</td>
<td>82</td>
</tr>
<tr>
<td>VIII. Correlations Squared (Percent Variance X 10^-2) for Reconstructions of Winter Temperature Using Model 7t15b15i and Actual Data for 1901-1962</td>
<td>84</td>
</tr>
</tbody>
</table>
ABSTRACT

Well-dated and replicated tree-ring chronologies from as many as 89 western North American sites are used to reconstruct past seasonal variations in pressure, temperature, and precipitation for North America and the North Pacific back to A. D. 1500. Climatic data from the twentieth century are related to tree-ring data by means of transfer functions which are then used to estimate past variations in each calibrated variable from past tree growth. Procedures are outlined for varying the calibration models that are employed, for selecting those calibration results which best reconstruct past climate, for combining models, and for relating the reconstructions to climatic factors other than those calibrated. A rigorous verification and analysis program is described which is expected to result in reliable and detailed first approximations of the seasonal patterns in past climatic variations. The spatial modes of climate reconstructed for North America and the north Pacific Ocean are to be compared to paleoclimatic and historical results obtained by other workers for the same areas as well as those obtained for the North Atlantic, Europe, and East Asia. New applications using the above reconstructions are to be examined and new methods developed for further calibration, verification, and analysis.

In order to expand the reconstructions to wider geographic areas or earlier time periods and to improve their quality, new tree-ring chronologies will be solicited through the International Tree-Ring Data Bank (which is to be supported by this project), through collaboration with scientists in different countries, and through a collection program of our own. This will include tree-ring dating, statistical processing, selection of the best chronologies and improved climatic grids, as well as the calibration of tree rings with climatic data.

Our best reconstructions will be applied to problems of climate, such as estimating the most probable modes and variations to be expected in the future, based upon the last four or five centuries of reconstructions and identification
of the causes of climatic variation and change. In addition, we will move
towards closer relationships with scientists in the U. S. S. R. and the
People's Republic of China in an attempt to extend the method to the entire
Northern Hemisphere. Eventually, as more data become available from the
Southern Hemisphere, we will examine the information from both hemispheres
for synchrony or lack of synchrony in the patterns of world climate.
I. INTRODUCTION

There is a growing awareness that climate does change, that the world's food and energy supplies may become increasingly affected by climatic variations, and that more effort needs to be directed to the task of anticipating future modes of climate. The winters of 1975-76 and 1976-77 are recent reminders of the variability which can be expected. It is also becoming apparent that climatic changes occur on all time scales and that our knowledge of the spatial and temporal character of climatic variations becomes less accurate as we work back in time from the present (Gates and Mintz, 1975).

One can be optimistic about the possibility of statistical forecasting of weather and climatic variations for a few days, weeks, or even months in the future because relatively good physical predictive models already exist, and there is a sufficient number of observations to develop the necessary statistics. However, there is insufficient knowledge of and a lack of studies on climatic variations for time scales of 1 to 1,000 years. Consequently, it is still difficult to anticipate changes in climate in this time scale. The lack is in part imposed by the unavailability of data. For example, the upper air records are about 30 years long, and surface records seldom exceed 100 years. A relatively small number of weather stations have long enough records to provide even 10 decades of independent observations, a number generally considered too small to derive meaningful statistics. In order to obtain more information on the nature of past climatic variability on time scales of years to millenia, it is necessary to go beyond existing weather records to proxy data, i.e., environmentally sensitive chronologies that have recorded past variations in climate for a particular region or site.
The various available proxies are not equal in their utility for climatic analysis. The most commonly used stratigraphic proxy sequences are best adapted for studies of very gradual climatic variations and changes occurring over periods lasting centuries or millenia. There are basically only three types of proxies available at present which are both continuous and sufficiently well-dated (to the specific year) to be useful in the study of climatic variations over periods less than 100 years: isotopes in ice cores, widths and contents of varves, and the widths, densities, and chemical properties of tree rings. Of these three sources, tree rings appear to be the most demonstrably reliable and are available from the widest geographical area. Therefore, they offer the greatest opportunity for reconstruction of a year-by-year record of climate over large areas of the globe. The widths of rings from stress-subjected trees are most useful at present because large quantities of data have already been collected, and the methods of analysis are sufficiently well studied and described (Fritts, 1976b).

In 1969 while working together in Wisconsin, H. C. Fritts and T. J. Blasing discovered that regression techniques coupled with principal component analysis provide a powerful tool for calibrating ring-width variations with corresponding anomalies in climatic factors (Fritts et al., 1971). If the climatic factors are used as statistical predictors of tree-ring width, the regression coefficients become response functions which express how the trees respond to climate. If the tree rings are used as the statistical predictors, the coefficients become transfer functions which transform ring-width variations into reconstructions of past climate. The response function was developed fully in the first years of our effort (Fritts, 1974). The transfer function is more complex and is being improved as we obtain more experience with the various types of data, model parameters, and verification requirements.
We learned very early in this work that the reconstructions from different models varied substantially, probably because each one described a somewhat different portion of the growth-climate system. There has been no single type of model that has been universally best. The optimum models varied depending upon which climatic variables were the predictands, and as a consequence, we were forced to test an array of models for calibration of each variable, each season, and each tree-ring grid. In addition, we learned that the reconstructions of several models could be combined to substantially improve the reconstructions beyond those of either of the original models considered separately.

Recent work also has focused on developing a number of climatological data bases including measurements of surface pressure, 700 mb pressure, average temperature, total precipitation, average sea surface temperatures, and drought severity indices, as well as other derived information related to climate. Considerable effort was directed to expanding the tree-ring data base to other sites, species, and areas of the world. An International Tree-Ring Data Bank and other appropriate data bases were established. One important result of this effort is the development of a new and larger tree-ring grid for western North America consisting of 102 chronologies. A number of new chronologies also were obtained for eastern North America and the American Arctic.

Transfer functions have been applied to hydrologic factors, biological phenomena, and agricultural problems, as well as to climatological relationships using the western North American tree-ring chronologies and a variety of climatic data forming large spatial fields. Several smaller diagnostic studies have been conducted in specific areas of western North America and in areas where trees grow under less climatic stress such as eastern North America and Europe. As a result of this continuing grant support, a world
The community of dendrochronologists and climatologists associated with the Laboratory of Tree-Ring Research and the International Tree-Ring Data Bank is focusing on problems of past climatic variation and change. The basis of these and other scientific developments relevant to climatic analysis is covered in a new book entitled *Tree Rings and Climate* (Fritts, 1976b) that has grown out of the work.

The purpose of this document is to summarize developments of the past year and a half representing the work supported by two grants with emphasis on the current status of the science and to outline our plans and proposals for the next three years. This document is organized into two progress reports on National Science Foundation Grant Nos. ATM75-22378 and ATM75-17034, a summary and discussion of the significance of the work, and a proposal for the two efforts which are to be continued as a single project beginning on October 1, 1977.

We are proposing that the research effort be continued at a level comparable to the sum of the two existing grants allowing for appropriate budgetary increases to keep abreast of inflation and to pursue the most promising opportunities resulting from current research developments. We also request a period of funding longer than one year to provide an uninterrupted opportunity to finish a number of nearly completed analyses, to compile and describe the results, and to expand the work to include a wider geographical area and a more extensive predictor grid.
II. CLIMATIC VARIATIONS FOR NORTH AMERICA AND THE NORTH PACIFIC SINCE A. D. 1500 AS IDENTIFIED BY WELL-DATED TREE RINGS (NSF Grant No. ATM75-22378)

The primary effort on this grant has been to obtain the best possible estimates of past climatic variation using the new set of 89 tree-ring chronologies as predictors and the newly developed computer software REconstruction PACKage (REPACK) to obtain the calibration and reconstruction. As mentioned earlier, it became apparent as work progressed that the reconstructions varied considerably from one statistical model to the next and from one climatic variable to the next. A variable such as precipitation, which is stored in the soil and which affects growth for a number of months after the event, is best reconstructed from growth lagged behind the occurrence of climate. A variable such as temperature, which affects growth immediately, is best reconstructed from the growth of the concurrent and prior season (presumably to allow for correction of autocorrelation in the growth sequence). It was also noted that if too few principal components were calibrated, the reconstructions were constrained to look like present-day climate, while if too many principal components were used, the error of reconstructions is inflated. In addition, calibrations passing significance tests for the dependent calibration period sometimes do not pass verification tests against actual data from the independent period outside the interval used for calibration.

Although our calibration, evaluation, and verification studies are not yet complete, we report that the major portion is behind us. The following pages outline what is involved in the process and then include a status report on the results. The most important developments are: 1) the transfer function analysis, 2) the variety of models used and tested in the calibrations, and 3) the analysis of reconstructions to select the best results to be used as a first approximation of past variations in climate.
A. The Transfer Function (Blasing and Carter)

The reconstructions are obtained by computing a transfer function \( mT_k \) which converts a set of \( m \) predictor variables (ring widths from trees on a variety of North American sites) into a set of \( k \) predictand variables (seasonal climatic factors over the North Pacific and the North American continent). Both the predictors and predictands are fields of variables over space, so the transfer function relates spatial anomaly patterns of annual ring width to spatial patterns of climate such as anomalies in winter temperature, precipitation, or pressure preceding the season of tree growth.

Reconstruction of climate by use of the transfer functions generally involves several operations as expressed by the following:

\[
\hat{Y}_{nk} = (X - \bar{X}_m)Sx^{-1} \beta_k \bar{Y}_k + \bar{Y}_k
\]

where \( X \) is a matrix of \( n \) observations of \( m \) predictor variables, \( \hat{Y} \) contains the corresponding \( n \) estimates of \( k \) predictand variables, and \( \beta \) is the matrix of canonical regression coefficients (Glahn, 1968, Equations 16-18). The diagonal matrices \( Sx \) and \( Sy \) contain the standard deviations of the \( X \) and \( Y \) variables, and the matrices \( Mx \) and \( My \) contain the means which are repeated \( n \) times (\( n \) rows) in Equation 1. The expression inside the brackets in Equation 1 is simply the normalization of \( X \). The normalized predictor data are then multiplied by \( \beta \) to obtain estimates of normalized values of each of the \( Y \) variables. These estimates are in turn denormalized via multiplication by \( Sy \) and the addition of \( My \).

Equation 1 can be written in simpler form in terms of the transfer function, \( T \), as follows:

\[
\hat{Y}_{nk} = X T_k - (Mx T_k - My)
\]
where
\[ T_k = S_x^{-1} \beta S_y, \]
and the expression in parentheses vanishes if the means of all predictor and predictand variables are zero.

Our particular data sets involve large numbers of variables (e.g., 65 ring-width chronologies, pressure at 96 grid points, temperatures at 78 stations, etc.), so we first reduce the data to principal components. These are analogous to the eigenvector representations in space and to the principal components, or amplitude coefficients, in time, described by Kutzbach (1967 and 1970). When both the predictor and predictand data are reduced to principal components, a matrix equation, which converts original predictor data (before principal components are extracted) into estimates of original predictand variables, is written as follows:

\[ \hat{Y}_k = \left( [X_{np} E_n - M_{np} S_{np}^{-1}] \beta^* S_b + M_{np} E_y'y_k S_y + M_y \right) \]

where the matrices \( E_x \) and \( E_y \) are the principal component eigenvectors corresponding to the \( X \) and \( Y \) variables and \( E_y' \) is the transpose of \( E_y \). The predictor principal components are then \( X E_x \) and the predictand principal components are \( Y E_y \). The matrices \( M_a \) and \( S_a \) represent the means and standard deviations of the predictor principal components, while \( M_b \) and \( S_b \) represent the means and standard deviations of the predictand principal components in a manner analogous to that used for the means and standard deviations of the original \( X \) and \( Y \) variables in Equation 1. Equation 3 can be rewritten as

\[ \hat{Y}_k = X T^* - (M_a S_{np}^{-1} \beta^* S_b E_y'y_k - M_b E_y'y_k S_y + M_y) \]

where
\[ T^* = E_x S_{np}^{-1} \beta^* S_b E_y'y_k S_y \]
is the appropriate transfer function and $\beta^*$ the corresponding set of canonical regression coefficients. If $Ma = Mb = My = 0$, only the first term on the right-hand side of Equation 4 remains, leaving $\hat{Y}$ expressed simply in terms of $X$ and the transfer function, $T^*$. If the eigenvectors in $Ey$ are derived from the covariance matrix of the $Y$ variables, rather than the correlation matrix, then $Sy$ is replaced by the identity matrix in Equations 3 and 4 since, in that case, the estimates of $Y$ are not in normalized form after multiplication by $Ey'$. In the work reported here, Equation 4 was used with $My = 0$ so that the predictand field is estimated in terms of departures from its mean.

The key step in obtaining $T^*$ is the determination of $\beta^*$, the matrix of canonical regression coefficients, which is used to directly estimate normalized values of $YEy$ from normalized values of $XEx_p$ (see Equation 3). The procedure for determining $\beta^*$ from the canonical correlations between the two sets of variables is outlined by Glahn (1968). The elements of $\beta^*$ are first computed by using only the largest canonical correlation, then the two largest, then the three largest, etc., until all are used. Each time a canonical correlation is added, the new $\beta^*$ is used to estimate $YEy$, and an $F$-ratio of mean squares is obtained as

$$F = \frac{(SSREG/dfu)}{(SSRES/dfr)}$$  

(5)

where the values on the right-hand side are:

$SSREG =$ the total sum of squares due to regression minus the sum of squares due to regression at the last preceding significant step (the total sum of squares due to regression when no previous significant step exists).

$dfu =$ the total number of degrees of freedom used since the last previous significant step (the number of predictor variables times the number of steps since the last significant step).
SSRES = the sum of squares of the residuals.

dfr = the number of degrees of freedom remaining in the residuals, adjusted for positive autocorrelation, if necessary.

If the first-order autocorrelation of the residuals, $r_1$, is positive, the necessary adjustment for dfr is made by multiplying the unadjusted value by $(1-r_1)/(1+r_1)$ as suggested in the World Meteorological Organization report on climatic change (World Meteorological Organization, 1966). The last step at which the F-ratio is significant at the 95% confidence level corresponds to the smallest canonical correlation used to determine the final $\beta^*$. All canonical correlations having lower values are deemed insignificant and are eliminated. Once $\beta^*$ is determined, the remainder of the transfer function is calculated in a straightforward fashion.

B. Model Construction (Blasing and Fritts)

Our statistical models discussed here are of the form of Equation 4 because the ring widths and climatic variables are reduced to principal components. Those principal component eigenvectors reducing less variance than the average of all eigenvectors are eliminated. They are determined by dividing 100% by the number of nonzero eigenvalues and eliminating those eigenvectors that reduce a lesser percentage of the variance than this quotient. Additional criteria can also be used to further reduce the number of principal component eigenvectors in both the predictor and predictand sets. This eventually may be done by an additional test using F-ratios for each canonical variable in the predictand set.

Lagging effects of the climate-tree-growth response and autoregressions in the time series of the ring widths have been taken into account in the following three ways:
1. The principal components of ring width for the growing season concurrent with or immediately following the climate (Variables I, Table I) and for growth of the next growing season (Variables F, Table I) are used together as predictors of climate. This model assumes that the climate-growth relationships can be represented simply as a lag in growth one or more years behind the occurrence of climate.

2. Each tree-ring chronology is adjusted to remove autocorrelation using the following equation:

\[ C_i = x_i - \rho(x_{i-1} - \bar{x}) \]  

(6)

where \( C_i \) is the adjusted ring-width data, \( x_i \) is the ring width for year \( i \), \( \rho \) is the first-order autocorrelation, and \( \bar{x} \) is the mean ring width.

The matrix of adjusted values is then subjected to principal component analysis, and these principal components are used as predictors of climate (Variables M, Table I), usually along with principal components of unadjusted ring-width data. Such a model assumes that the relationship is some kind of autoregressive one and that the differences between data with and without autoregression can be used in climatic reconstruction.

3. The principal components of growth of the season before the climate (Variables B, Table I) and the growth concurrent with climate (Variables I, Table I) (or immediately following climate in the case of autumn and winter) are used as predictors of climate. Such a model allows for separation of the autoregressive effect from the nonautoregressive one by including prior growth as part of the predictor set.

Various combinations of lagged and nonlagged ring-width data, with and without autocorrelation removed, have been calibrated with climate for each
TABLE I

Summary of Models Calibrated
(The Highest Percentage of Climatic Variance for Year t Calibrated by Each Type of Model Using Tree Rings from Years t-1, t, t+1, and t+2 as Predictors. Inserted Table Includes Results In Which Only Climatic Data Were Used to Estimate Other Climatic Data.)

<table>
<thead>
<tr>
<th>PREDICTANDS</th>
<th>PRESSURE</th>
<th>TEMPERATURE</th>
<th>PRECIPITATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Spring</td>
<td>Summer</td>
<td>Autumn</td>
</tr>
<tr>
<td>RING-WIDTH PREDICTORS FROM YEAR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>t-1</td>
<td>t</td>
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</tr>
<tr>
<td>65 Stations</td>
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</tr>
<tr>
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<td></td>
<td>I,F</td>
<td>39.6(3)</td>
<td>40.6(5)</td>
</tr>
<tr>
<td></td>
<td>H,F</td>
<td>19.1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>I,M,F</td>
<td>30.1</td>
<td>13.7</td>
</tr>
<tr>
<td></td>
<td>I,M,F</td>
<td>30.1</td>
<td>13.7</td>
</tr>
<tr>
<td></td>
<td>F,M(F)</td>
<td>27.4</td>
<td>36.3</td>
</tr>
<tr>
<td></td>
<td>F, M(F)</td>
<td>27.4</td>
<td>36.3</td>
</tr>
<tr>
<td>40 Stations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>18.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I,M</td>
<td>21.3</td>
<td>24.7</td>
<td></td>
</tr>
<tr>
<td>I,F</td>
<td>27.8</td>
<td>28.6</td>
<td>20.7(2)</td>
</tr>
<tr>
<td>F</td>
<td>29.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F,F</td>
<td>29.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>89 Stations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>24.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>20.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I,F</td>
<td>33.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M,M(F)</td>
<td>14.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTALS</td>
<td>14</td>
<td>27</td>
<td>17</td>
</tr>
</tbody>
</table>

NOTE: Lettering convention is as follows: B indicates year t-1 (before climate of year t), I indicates year t (immediate), F indicates year t+1 (following climate of year t), FF indicates year t+2 (two years following climate of year t), and M indicates that the first-order autocorrelation has been removed (missing) from the ring-width data. Italics indicate the largest value in the column.

aPercentages given are the largest obtained for a model of the type listed, except as noted (see footnotes b and c below). Numbers in parentheses indicate the number of models of a given type that were run if more than one was run.

bMore variance has been calibrated using a model of this type by forcing small-scale eigenvectors into the model. The percentage given corresponds to a model chosen by methods discussed in the text.

cModel(s) incorporate eigenvectors which reduced less variance than would have been reduced by random numbers. A zero indicates that no statistically significant calibration was achieved.
season. The period of calibration (1899-1963, inclusive) varies slightly as different seasons are considered, as different climatic variables are used, and as ring-width data at different lags are included. The minimum length for a given calibration is 61 years; the maximum is 65. The calibrations may involve different numbers as well as different kinds of variables:

1. The number of principal components in either the predictor or predictand ranges from a minimum of three (representing the eigenvectors corresponding to only the most common climatic or growth anomaly types) to a maximum of 20, if there are that many principal components above the random noise level in the system.

2. The principal components of tree growth used to reconstruct climate in a given year $t$ may be chosen from years $t-1$ through years $t+2$. No more than a total of 30 principal components are used as predictors in any one model so that with approximately 60 years of calibration data, enough degrees of freedom are retained to assure valid significance tests.

3. As mentioned above, tree-ring predictor data include principal components of either actual ring-width index data or data with first-order autocorrelation removed.

A total of 169 valid models have been calibrated thus far using our newly developed job stream, REPACK, and the percentages of variance for the calibrations are included in Table I. We expect to run approximately 100 additional calibrations (to fill the absent cells in Table I) to complete the model assessment. We also expect to obtain additional calibrations as new variable sets, such as different tree-ring grids, different climatic variables, or different climatic station locations, become available. In addition, we have
obtained significant improvements by combining results from two or more different models, averaging the reconstructions, and testing them against actual independent data.

A complete set of programs to perform all of the above functions (REPACK) is working properly, and an instruction manual for its use is being prepared. Some of the programs have already been supplied to cooperating scientists, and as the errors are identified and eliminated, we will generalize the directions and input and make the programs available for general scientific use.

C. Model Evaluations (Blasing, Fritts, and Winter)

The results from each calibration are evaluated by comparing the estimated predictand values in the calibration period with the actual data. The most conventional summary statistic is the overall percentage of predictand variance that was calibrated (see Table I). It is also possible to compute the percentage of variance calibrated for each of the predictand principal components. In our analyses where the variables are spatial fields (e.g., the temperature at each of 78 stations), the calibrated variance also is portioned out to each station and plotted on a map. Contours are then made to assess geographic areas of good and poor agreement. The means, standard deviations of the residuals, and reduction of error are also plotted on additional maps. Other statistics also are obtained from the computer output.

The first-order autocorrelation of the residuals for each predictand principal component is computed, and these are used in adjusting the degrees of freedom for the F-test described earlier. Similar autocorrelations also are obtained for: 1) the estimated values of the predictand principal components, 2) their actual values, and 3) the actual values of the predictors
(principal components of tree growth). These values are compared to assess how well autoregression is handled by the model.

Statistics are computed which measure the similarity of the actual and predicted data fields for each year of the calibration interval. These are: the correlation coefficient, its square, and the reduction of error statistic (Fritts, 1976b).

One way to summarize the pressure reconstructions is to correlate each reconstructed spatial anomaly pattern with each characteristic anomaly type-pattern originally described by Blasing (1975b). A pattern of actual or reconstructed pressure data is classified as a particular type when the correlation coefficient between the data and type is greater than a specified value, $r^*$. Four levels of $r^*$ (0.3, 0.4, 0.5, and 0.6) are used. For each level, counts are made of the occurrences of type-patterns above the specified value of $r^*$ for both the actual and reconstructed pressure anomaly sets. These occurrences are converted to: 1) the frequency of each type occurring, given that it was reconstructed and, 2) the frequency of each type being reconstructed, given that the type did occur. Contingency tables are produced which are used to assess the capability of a model to reconstruct each type with the correct frequency and to place the reconstructed type in the correct year.

It is also important to consider the following questions: 1) If a particular climatic situation is reconstructed, did a similar situation actually occur, and how often did something entirely different occur? 2) If a particular climatic situation actually occurred, was it essentially reconstructed, and how often was something entirely different reconstructed? 3) How well does
a model reconstruct anomalous situations which occurred frequently in the
modern record (typed years)? 4) Does a model reconstruct anomalous climatic
situations which were infrequent in the modern record as well as it reconstructs
more frequent ones which were classified as types? 5) Does a model tend to
reconstruct certain situations much more (or less) frequently than they
actually occurred?

The following objective scheme has been developed to help answer these
questions. The set of six or more models having the best overall statistics
described above are selected for this detailed examination which involves
computing eight diagnostic statistics, A1 through A8.

Using $r^* = 0.30$ as described above for pressure type-pattern recognition,
the lesser of the two conditional probabilities described on the previous page
is tabulated to provide the most optimistic estimate of correspondence
between actual type data and the reconstructed types. Percentages are obtained
for each type separately, and the values are averaged. The procedure is then
repeated using $r^* = 0.50$ to obtain a similar average. The average of these
two averages, A1, provides estimates of how well the predominant atmospheric
pressure anomaly patterns are reconstructed.

The following data are also tabulated. Using the type classification of
actual data for each year ($r^* = 0.50$), the statistics for the individual
yearly reconstructions are examined by counting the number of cases in which
the reconstructed values and actual data are negatively correlated and the
number of cases in which the reduction of error is negative. These two
counts become statistics A2 and A3, which, in a sense, are the inverse of
statistic A1; they are proportional to the number of typed years in which the
reconstructions contradict the actual data. When values are small, the
reconstruction of that particular type is good.
The type classifications of the reconstructions are examined, as were the actual data in the preceding test, and those cases with negative correlations and negative reduction of error are counted. These counts are tabulated as statistics A4 and A5. In addition, all years in which the actual data are not identified as being of a particular pressure type are examined, and the negative values of the same statistics are counted. These counts are tabulated as statistics A6 and A7. These numbers express how poorly we do in the remaining years not classified as a particular pressure type.

For the final statistic the number of occurrences of each type in the reconstructions is divided by the number of occurrences for each type in the actual data, and the absolute difference of the ratio from a value of 1.0 is tabulated. This departure is summed over all types to obtain an index to over or undertyping, A8.

When the statistics A1 through A8 are compiled for all six selected models for a particular season, each model is ranked for each statistic, and the ranks interpreted in terms of model strengths and weaknesses. For example, a winter model incorporating ring-width data at lags 0 and 1 did the best job of reconstructing untyped situations (ranked first in both A6 and A7 categories), while a model incorporating only nonlagged tree-ring variables did the best job on typed years (ranked first in each of the categories A2 through A5). This indicates that the lagged model is more likely to correctly reconstruct past variations in climate that were infrequent (and thus untyped) during the calibration interval than the nonlagged model.

The sum of the eight rankings for a given model can also be used as a total score (a low score corresponding to a better model). These scores
usually give the same relative rating to a model as is obtained by comparing
the percentages of calibrated variance, but in cases where the calibrated
variance of two models is close, this independent evaluation provides an
additional objective basis for making a choice. Sometimes two or more models
with about equal total scores may differ in their strengths and weaknesses.
Since all the reconstructions are on file, any of the models can be selected
for use depending upon the objective of the analysis.

The reconstructions from a number of models are also compared by means of
a three-way analysis of variance which treats the results for A number of
years, B models, and C grid points. The mean squares and estimated component
variances for the three factors and their interactions are calculated along
with a two-way analysis of variance and additional statistics for each year
of reconstruction.

This information will tell us: 1) In what periods of time are our recon-
structions most consistent? 2) How does the error change as we go backwards
does the model error behave from one model to the next and over the spatial
grid? 5) What variance is common to all reconstructions? 6) How do the
above statistics vary from one period of time to the next and from one season
to the next? Several trial runs have been completed on 50-year intervals
using reconstructions from six different pressure models and all four seasons.
We are now running the final analyses of variance by the 50-year intervals and
by seasons on the six best models selected for each season and variable.

We also plan to apply the variance analysis to pressure reconstructions
for a given model applied to the 89-, 65-, and 40-station tree-ring sets for
1700-1962 (Fritts and Shatz, 1975) and to the temperature and precipitation reconstructions, if the information gained from the analysis proves worth the program modifications necessary to handle these two data sets. Such results would provide objective measures of the variations due to tree-ring grid differences and to differences in the climatic variables reconstructed.

The results obtained so far are encouraging, as they indicate that a large amount of variance (approximately 50%) is common among all reconstructions. As we exclude the models that are obviously poor, we expect to raise this percentage significantly.

D. Independent Verification (Lofgren, Ares, and Fritts)

The final test of a model is to compare reconstructed climatic values with independent climatic data, that is, data from time periods outside the calibration interval. A set of programs has been developed to read monthly temperature (or precipitation) data from magnetic tape for stations that have been used in calibration to form yearly seasonal averages and then to compare the data to the reconstructions. Stations selected were those which had a minimum of 15 independent years for both temperature and precipitation. Two sets are compared by calculating the reduction of error, the correlation coefficient, the product means, and counts of two different sign tests (Fritts, 1976b). Theoretical values for the 0.95 limits are also calculated. The same set of tests is made for the time series after the data are smoothed by a two-year moving average, and the verification tests are repeated for both the dependent and independent time periods.

The verification work has just begun in earnest because only recently have temperature and precipitation reconstructions been completed using
REPACK. Verification will be the final assessment necessary to assure that the reconstructions do resemble past climates. We have already revised our ideas about some apparently promising models and find that for some models the reconstructions in the West are much better than those in the East (a fact that is not surprising). When the task is finished, we will have confidence that our choices are the best reconstructions of yearly climatic variations that are possible, given the present state of the discipline, and we will know how far beyond the existing tree-ring grid the reconstructions are valid. Table II summarizes the verification results for a set of 17 of 78 climatic stations from western North America for models in which the number of predictand eigenvectors was altered. The numbers in the table indicate the number of stations of the 17 for which that particular test was significant.

The calibration statistics (percent variance calibrated) for all six models were significant, yet the reconstructions from the two "IM" models failed all but six of 85 verification possibilities. The four "BI" models shown on the left of the table passed many more tests than could have occurred randomly. It is also evident from the table that the 7t15b15i model on the left, which incorporates all seven of the greater-than-noise-level eigenvectors of temperature, provides the greatest number of significant verification statistics. As the number of eigenvectors decreases to below seven, both the calibration variance and the number of verification successes diminishes.

The fact that the 4t15b15i\textsuperscript{b} model (column 4), in which we excluded insignificant canonical steps, held up on more independent verification than the 4t15b15i\textsuperscript{a} model (column 3), suggests that the F-test employed to screen out insignificant canonical variates may be too stringent in cases where the
## TABLE II
Calibration and Verification Statistics for Six Winter Temperature Models

<table>
<thead>
<tr>
<th>Model</th>
<th>7t15b15i</th>
<th>6t15b15i&lt;sup&gt;a&lt;/sup&gt;</th>
<th>4t15b15i&lt;sup&gt;a&lt;/sup&gt;</th>
<th>4t15b15i&lt;sup&gt;b&lt;/sup&gt;</th>
<th>7t15i15m</th>
<th>14t15i15m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calibration Statistics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent variance calibrated</td>
<td>36.5</td>
<td>35.1</td>
<td>26.0</td>
<td>46.7</td>
<td>21.8</td>
<td>42.8</td>
</tr>
<tr>
<td>Number of years in which actual and reconstructed grids were negatively correlated</td>
<td>7</td>
<td>11</td>
<td>18</td>
<td>6</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>Number of years in which the reduction of error during calibration period was negative</td>
<td>31</td>
<td>32</td>
<td>39</td>
<td>24</td>
<td>38</td>
<td>21</td>
</tr>
<tr>
<td>Number of stations (out of 17) passing verification on independent data (95% level)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Correlation</td>
<td>8(0)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>6(2)</td>
<td>3(3)</td>
<td>9(0)</td>
<td>0(0)</td>
<td>0(0)</td>
</tr>
<tr>
<td>Reduction in Error</td>
<td>4(1)</td>
<td>4(3)</td>
<td>1(2)</td>
<td>1(2)</td>
<td>0(0)</td>
<td>0(0)</td>
</tr>
<tr>
<td>Product Mean</td>
<td>0(4)</td>
<td>1(4)</td>
<td>0(0)</td>
<td>1(7)</td>
<td>0(3)</td>
<td>1(1)</td>
</tr>
<tr>
<td>First Difference</td>
<td>1(3)</td>
<td>0(1)</td>
<td>1(0)</td>
<td>1(3)</td>
<td>1(0)</td>
<td>1(0)</td>
</tr>
<tr>
<td>t-test</td>
<td>3(3)</td>
<td>5(2)</td>
<td>2(0)</td>
<td>2(5)</td>
<td>3(0)</td>
<td>4(0)</td>
</tr>
<tr>
<td>Stations passing at least one test; number of</td>
<td>9(2)</td>
<td>8(2)</td>
<td>4(4)</td>
<td>9(3)</td>
<td>3(1)</td>
<td>5(2)</td>
</tr>
</tbody>
</table>

**NOTE:** B, I, and M refer to the year of the predictor (tree-ring) eigenvector amplitude used in reconstructing the climate for year t. B indicates year t-1; I indicates year t; M indicates the first-order serial correlation removed for year t.

<sup>a</sup>The first six (or four) temperature eigenvectors were used in calibration and reconstruction.
<sup>b</sup>Temperature eigenvectors 1, 2, 3, and 5 were used in calibration and reconstruction. This model was forced to select the same final step of the canonical correlation as the 7t15b15i model.
<sup>c</sup>Numbers in parentheses are additional stations that passed the significance test after the time series were smoothed over two years.
total number of possible canonical variates is limited (four in this example). A series of tests is being designed to help us identify 1) how large a model must be and what F-tests must be used to assure that enough of the major modes of variation are included in calibration, and 2) what is the upper limit of model size where additional small modes of variation contribute less information than they add to the error of analysis? The appropriate tests may involve recalibration of a good model using different numbers of eigenvectors and the results compared as to the amount of independent verification.

E. Data Retrieval and Analysis

We have developed a number of interactive and batch computer programs capable of accessing any of the climatic reconstructions and enabling us to perform a variety of analyses. The programs allow the user to specify exactly which data file is to be selected from the magnetic tape, to make certain computations, and to arrange or plot the results in various ways. Each program is summarized in the remainder of this section. Four are more specialized programs designed for specific types of data handling and analysis. Two of the programs fall more logically within the domain of the second research grant but are presented here to simplify the organization of this report.

1. Program PRMAP (Stevens)

This is a mapping program for use with surface or 700 mb pressure, either actual data or reconstructions. The user specifies the source of the data to be mapped, the number of maps to be generated, and years to be averaged for each map if averaging is desired. Either sequential or random-year
selection may be made for each map, and differences between a specified and a reference map may be computed. The reference map may be any map generated by the program or a map previously generated and stored on the computer. Base maps are printed for the 96-point grid with data values at the appropriate locations. The standard deviations of the residuals are also read from the tape and used to calculate standard errors and t-tests of mean values. Those data with an associated t-value equal to or exceeding 2 are flagged by asterisks. The mean data values, standard errors, and t-values for each map also are printed on a separate page of the output. Data generated by this program also may be stored in a computer file for subsequent analysis.

2. Program DIFFMAP (Winter)

This program performs the same operations as PRMAP except that it is designed for temperature or precipitation reconstructions and uses the CDC 6400 computer rather than the DEC-10 system. The output is on a map of the United States with the mean anomalies in temperature (or precipitation) for single years or averaged for more than one year.

3. Programs PRTIME and CLTIME (Stevens)

These programs are discussed together because they do the same thing but use different input data: pressure data for PRTIME; temperature or precipitation data for CLTIME.

The programs allow the user to select the appropriate file on a magnetic tape, to specify the grid points or stations to be used, to extract a time series for the specified points (or stations), or to manipulate the data to obtain an averaged time series for a group of specified grid points or stations. In the latter case, standard errors of estimate are calculated.
Values of the selected time series are printed and cataloged on a computer file for subsequent use.

4. Programs PLOT and CCOMP (Stevens)

Again these two programs do the same thing, but the output is different. PPLLOT plots any of the above time series on the line printer, and CCOMP plots them on the CALCOMP plotter. PPLLOT is generally used for a "quick look" at a time series, while CCOMP would be used to prepare plots for display and publication (see Fig. 7).

Both programs calculate and print the basic statistics of each series being plotted: mean, standard deviation, first-order serial correlation, minimum and maximum values. They also offer several options: high- or low-pass filtering, normalization, choice of four plotting scales, scaling factor, and scale offset. CCOMP also offers a choice of three scaling factors for the time axis.

5. Program NORM (Duvick)

This interactive program normalizes growth departures (from the mean) for one or more specified sets of years. The departures are then plotted in the correct location on a map of the western United States produced on the line printer (Fig. 1). The program allows selection of any desired normal period and up to 25 different sets of years (each one containing up to 350 years). The years may be selected at random or specified as a sequence. A standard error is computed, and those means greater than a specified t are marked as significant by replacing the decimal point with an asterisk on the map printout.
Figure 1. The anomaly in tree growth from 1601–1900 for the 65 selected tree-ring chronologies used in calibration. The units are normalized departures from the 1901–1963 mean using the 1901–1963 standard deviations. Shading indicates departures equal to or less than −0.5. Note the low growth throughout the Great Basin and central Rocky Mountains indicating general drought there.
6. Programs XFER and SIMUL (Stevens)

As described earlier in this report, a statistical relationship between two sets of variables may be expressed as a simple transfer function (see Equation 2).

The transfer functions, $T$, are associated with original variables and must be calculated from the $\beta$ matrix and other data obtained in the calibration. The $T$ matrix is useful for a variety of tests and analyses since it can be interpreted as a set of multiple regression coefficients.

Program XFER performs the actual calculations necessary to generate the transfer function for a given model using the eigenvectors and the $\beta$ matrix produced in the calibration. The resultant set of values from Program XFER is then used by Program SIMUL to transfer specified input data into an output representing the estimates of the predictand.

Two examples illustrating the use of these programs are described as follows: Using our standard techniques on observed data, we obtained a calibration relating surface pressure to heights of the 700 mb surface. We calculated the set of transfer functions and then used program SIMUL to estimate past 700 mb height anomalies corresponding to the surface pressure reconstructions. The results are not necessarily reliable reconstructions because they used reconstructions to obtain additional reconstructions. They should be useful, however, in describing the kind of variations in other climatic variables, such as 700 mb heights, which are associated with surface pressure reconstructions.

Another use of these programs, although we have not tried it at the time of this writing, is the study of model sensitivity to changes in the predictors.
Different values may be substituted for certain predictor variables, and the effects of these values on the reconstructions are obtained from the output of the transfer function. We can also study the transfer functions used to reconstruct temperature (or precipitation) from pressure, or the reverse. By substituting values for temperature at specified climatic stations or grid points, we obtain a map of the corresponding pressure changes associated with such temperature changes.

7. Program PROB (DeWitt and Lofgren)

One reason for reconstructing past climate is to extend our short historical record of temperature and precipitation into the past to provide a larger sample from which more useful probability statements can be made to estimate future climatic variation. However, the regression estimates of past climatic variation may be forced by statistical constraints to have less variance than the actual data.

Program PROB corrects the reconstructed values for this difference in variance and calculates the frequency of occurrences of specified temperature (or precipitation) classes both from actual data for the calibration period and from the reconstructed estimates since 1601. Probability estimates for the specified classes based on the reconstructed values from one or more intervals of time within the calibration record can then be determined. In correcting for the reduction of variance of the reconstructed values, the program compares the standard deviations of the actual and reconstructed values for a "control" set of years within the calibration period, then multiplies the reconstructed values by the ratio of the two standard deviations before adding the actual
mean to convert to degrees Farenheit or Centigrade, or inches or centimeters of precipitation, as follows:

\[ \hat{y}' = (\hat{y}_i - M_r) \frac{S_a}{S_r} + M_a \quad (7) \]

where \( \hat{y}' \) is the denormalized value of the reconstructed climatic variable corrected for possible reduced variance of reconstructed values; \( \hat{y}_i \) is the reconstructed value for year \( i \) in standardized units; \( M_r \) is the mean of the reconstructed values during the control period; \( S_a \) is the standard deviation of the actual data during the control period; \( S_r \) is the standard deviation of the reconstructed values during the control period; and \( M_a \) is the mean of the actual data during the control period.

The frequency of occurrence in each chosen class (for example, two-degree classes for temperature or half-inch classes for precipitation) for a period prior to 1901 can then be compared with the frequency of occurrence during the control period. The program can then examine other specified intervals using the corrected reconstructions as well as recalculating the frequencies. If the frequencies in each period differ from those of the control interval, it will be expressed as a change in probability. Chi square and the coefficient of contingency are used to measure the associations between the contingent frequencies.

This program is nearly completed, and within the next month we plan to test its utility. It is hoped that it will enable us to assign more meaningful numbers and probabilities to the reconstructed variations than can be obtained from simple plots or comparisons of means and variances. As an example, our reconstructed mean anomaly maps indicate generally cooler temperatures in the past than in the present for large areas of eastern North America. We
hope that Program PROB will allow us to make concrete statements using the record from 1601-1970 concerning the probability that the mean winter temperatures will be below a critical value such as 32°F and to compare this likelihood with frequencies calculated for the 1931-1960 normal period. It is hoped that such data will be more easily equated to energy consumption or other economic variables than data in their present form of regression estimates.

8. Program TREND (Blaing)

This program correlates several time series, \( x_1(t) \), with time, \( t \), to identify trends. For example, monthly temperature values for each year of a specified period are read in for each of several stations. Then the program calculates the correlation coefficient, the monthly temperatures, and the corresponding year number (time) for each station. This is done for each of the twelve calendar months as well as for the annual average temperature. The results are then plotted as maps of temperature trends for the period analyzed. Trends can also be determined for any season (group of months) desired.

In addition to its value for analyzing climatic variation and change in the present and the past, this program is useful for comparing trends of several neighboring stations to identify nonhomogeneous data in the existing record due to factors such as urban warming.

Such programs as this can be used to analyze data at over 100 stations for long time periods at virtually negligible time and dollar cost because of the large and easily accessible climatic data bank which has been entered on tape files over the years at the Laboratory of Tree-Ring Research.
9. Program MERGE (Stevens)

This program creates an extended tree-ring chronology by merging two chronologies having acceptable crossdating but different means and variances in the overlap period.

The creation of the extended chronology is a four-step process. The first three steps operate on the chronology with the earlier starting date and adjust its index values so that the means and variances for the overlap period of both the high-frequency and low-frequency components are comparable with those for the other chronology. The two components are treated separately and then combined to produce the adjusted values. The fourth step creates the merged chronology by combining the indices in the overlap period by weighting them according to both position in the overlap period and the number of radii used in the chronology. The results of each manipulation are saved so that the investigator has the option of choosing the one best adapted for his analysis.

10. Program DTYPE (Stevens)

This program was written to enable us to select desired data from a computer file of Dzerdzevskii's Northern Hemisphere circulation types obtained from Dr. Eberhard Wahl at the University of Wisconsin, Madison.

The file contains a type classification (1 of 41 types) for each day from January 1, 1899 to December 31, 1969. The program allows the user to pool the data for specified months, years, and/or types, and lists the number of occurrences of each grouping. An option also permits the specification of a set of years as a reference period and converts the output data to departures from the reference period. A chi square analysis tests for nonrandom differences. This program was used extensively in analyses prepared by Katherine Hirschboeck and discussed in Section IIIG of this report.
11. Program TYPSEQ (Carter)

   This program examines the occurrences of pressure anomaly types for a given
season and counts the occurrences of types of a specified season which preceded
or followed them. The user specifies the season against which other seasons
are to be compared, the initial year, and cutoff level for $r^\star$, and allows
for a total of three other seasons which may be compared against the first.
The input consists of the correlation coefficients between each actual or
reconstructed anomaly pattern and the type patterns for each season. A year
is used in determining the counts and frequencies which are tabulated if and
only if the correlation coefficient ($r^\star$) between that year and the type with
which it is most highly correlated is greater than or equal to the cutoff
level specified by the user.

12. Program CROSS (Stevens)

   This interactive program extracts data for specified years from two user-
specified files containing time series data. It then calculates and prints
the mean, standard deviation, minimum, maximum, and first-order serial
correlation for each data set, plus the coefficient of cross correlation
between the sets and its square. An option allows both high- and low-pass
filtering of the data and recalculation of the statistics for each filtered
set.
III. APPLIED RESEARCH RECONSTRUCTING PAST CLIMATE OF THE NORTHERN HEMISPHERE BY USE OF TREE RINGS (NSF Grant No. ATM75-17034)

The primary effort on this project is to expand the present tree-ring technology to new species and data grids, to develop new methods of analysis, and to attempt new applications as the opportunity arises. The present status of tree-ring collecting and archiving work is described; specific experiments and some new applications are included; and the basic analyses of climatic variation are summarized. A number of the items that were included in the previous section under Data Retrieval also fall under the jurisdiction of this project.

A. Status of Tree-Ring Collections and Mergers (DeWitt and Wiseman)

A total of 111 high-quality chronologies from the contiguous United States and nearby areas of Mexico have been collected and processed under the auspices of ARPA Grant No. AFOSR 72-2406 and NSF Grant No. ATM75-17034. An additional 27 chronologies from Arctic and European sites have been collected and/or processed as part of the same project. For lists of the chronologies included in these sets, see Tables I-III in Fritts et al., 1976, and Table III of this report.

Of the total of 138 completed chronologies in the set of collections funded by the above two grants (which includes Arctic and European sites discussed later in this report), 63 have been submitted to and accepted by the International Tree-Ring Data Bank, which is discussed in Section IIIB by J. A. Sherwood. The remainder are included in the Laboratory of Tree-Ring Research Data Base. Collection efforts outside the United States involved scientists from the countries concerned or were obtained with the full knowledge and consent of the respective governments.
# TABLE III
Chronology Status Revisions Made During the Period of This Grant

<table>
<thead>
<tr>
<th>Reference&lt;sup&gt;a&lt;/sup&gt;</th>
<th>ID Number</th>
<th>Site Name</th>
<th>Species&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Time Span</th>
<th>Completed</th>
<th>Cores</th>
<th>Trees</th>
<th>Collectors&lt;sup&gt;c&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-3&lt;sup&gt;d&lt;/sup&gt;</td>
<td>559898</td>
<td>Camel's Hump A + C, VT (summed)</td>
<td>PCRU</td>
<td>1635-1971</td>
<td>Yes</td>
<td>36</td>
<td>18</td>
<td>TGS</td>
</tr>
<tr>
<td>A-8</td>
<td>38884M</td>
<td>Montgomery Co. + Big Brushy Mtn., AR (merged)</td>
<td>PIEC</td>
<td>1666-1972</td>
<td>Ready for merging</td>
<td>80</td>
<td>59</td>
<td>REB, FH, MAW, CWS, JBH</td>
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<tr>
<td>A-8</td>
<td>311819</td>
<td>Polk Co., AR</td>
<td>QUAL</td>
<td>1677-1939</td>
<td>Yes</td>
<td>24</td>
<td>12</td>
<td>REB, FH</td>
</tr>
<tr>
<td>A-8</td>
<td>35481M</td>
<td>Polk Co. + Brush Heap Mtn., AR (merged)</td>
<td>QUAL</td>
<td>1676-1972</td>
<td>Ready for merging</td>
<td>49</td>
<td>26</td>
<td>REB, FH, MAW, CWS, JBH</td>
</tr>
<tr>
<td>A-9</td>
<td>38481M</td>
<td>Pope Co. + Russellville, AR (merged)</td>
<td>QUAL</td>
<td>1642-1972</td>
<td>Ready for merging</td>
<td>55</td>
<td>27</td>
<td>REB, FH, CWS, JBH, MAW, EE</td>
</tr>
<tr>
<td>A-10</td>
<td>387818</td>
<td>Estes Winona + Mark Twain Nat. For., MO (merged)</td>
<td>QUAL</td>
<td>1780-1972</td>
<td>Yes</td>
<td>54</td>
<td>27</td>
<td>EE, MAW, CWS, JBH</td>
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<tr>
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<td>Carter Co. + Mark Twain Nat. For. + Winona, MO (merged)</td>
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<td>1642-1972</td>
<td>Ready for merging</td>
<td>108</td>
<td>69</td>
<td>MAW, CWS, JBH, EE</td>
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<tr>
<td>A-11</td>
<td>38681M</td>
<td>Shannon Co. + Soc. Am. Foresters Plot, MO (merged)</td>
<td>QUAL</td>
<td>1588-1972</td>
<td>Ready for merging</td>
<td>60</td>
<td>48</td>
<td>REB, FH, MAW, CWS, JBH, EE</td>
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</table>

<sup>a</sup>See Figure 1 (sites designated here by "A") and Figure 3 (sites designated here by "B"), pp. 11 and 23, Fritts et al., 1976. Additional map sites reported here are A-37 (Traveler Mtn. and Gero Island, ME) and B-20 (Thelon Game Sanctuary, NWT, Canada).

<sup>b</sup>See Key to Species on p. 17 of Fritts et al., 1976.

<sup>c</sup>See Key to Collectors on p. 18 of Fritts et al., 1976. Additional collectors reported here are J. Dennis and L. E. Conkey.

<sup>d</sup>Italics indicate changes or additions since last reporting in Fritts et al., 1976.
Table III, cont.

<table>
<thead>
<tr>
<th>Reference</th>
<th>ID Number</th>
<th>Site Name</th>
<th>Species</th>
<th>Time Span</th>
<th>Completed</th>
<th>Cores</th>
<th>Trees</th>
<th>Collectors</th>
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<tbody>
<tr>
<td>A-12</td>
<td>43181M</td>
<td>Warren Co. + Falls Creek</td>
<td>QUAL</td>
<td>1669-1972</td>
<td>Ready for</td>
<td>60</td>
<td>38</td>
<td>REB, FH, MAW,</td>
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<tr>
<td></td>
<td></td>
<td>Falls White Oak, TN (merged)</td>
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<td></td>
<td>merging</td>
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<td></td>
<td>CWS, J BH</td>
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<tr>
<td>A-15</td>
<td>438840</td>
<td>Norris Watershed Bdry., TN</td>
<td>PIEC</td>
<td>1681-1972</td>
<td>Yes</td>
<td>20</td>
<td>10</td>
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<tr>
<td>A-16</td>
<td>418890</td>
<td>Newfound Gap, NC</td>
<td>PCRU</td>
<td>1686-1972</td>
<td>Yes</td>
<td>24</td>
<td>12</td>
<td>MAW, J BH</td>
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<tr>
<td>A-26</td>
<td>338579</td>
<td>Tasajera, Baja, Mexico</td>
<td>PIJE</td>
<td>1560-1971</td>
<td>Yes</td>
<td>32</td>
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<tr>
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<td>349570</td>
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<td>PIJE</td>
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<td>Yes</td>
<td>40</td>
<td>20</td>
<td>MAS, TPH, SBC</td>
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<tr>
<td>A-37</td>
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<td>Traveler Mtn., ME</td>
<td>PCRU</td>
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<td>L. E. Conkey</td>
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<tr>
<td>A-37</td>
<td></td>
<td>Gero Island, ME</td>
<td>PIST</td>
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<td>L. E. Conkey</td>
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<tr>
<td>B-2</td>
<td>628</td>
<td>Ft. Chimo Site 1-L, Quebec,</td>
<td>LALA</td>
<td>1650-1974</td>
<td>No</td>
<td>31</td>
<td>14</td>
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<tr>
<td></td>
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<td>629</td>
<td>Ft. Chimo Site 2-L, Quebec,</td>
<td>LALA</td>
<td>1752-1974</td>
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<td>6</td>
<td>3</td>
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<td>B-2</td>
<td>637</td>
<td>Ft. Chimo Site 3-L, Quebec,</td>
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<td>1677-1974</td>
<td>No</td>
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<td>B-2</td>
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<td>Ft. Chimo Site 4-L, Quebec,</td>
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<td>1641-1974</td>
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<td>45</td>
<td>18</td>
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<tr>
<td>B-20</td>
<td>19974</td>
<td>Thelon Game Sanctuary, NWT,</td>
<td>PCGL</td>
<td>1574-1969</td>
<td>No</td>
<td>20</td>
<td>20</td>
<td>J. Dennis</td>
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<td></td>
<td></td>
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<tr>
<td>B-3</td>
<td>862749</td>
<td>Nain A, Labrador, Canada</td>
<td>PCGL</td>
<td>1801-1973</td>
<td>Yes</td>
<td>18</td>
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*forest interior*
<table>
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<th>Reference</th>
<th>ID</th>
<th>Site Name</th>
<th>Species</th>
<th>Time Span</th>
<th>Completed</th>
<th>Cores</th>
<th>Trees</th>
<th>Collectors</th>
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</thead>
<tbody>
<tr>
<td>B-3</td>
<td>861749</td>
<td>Nain B, Labrador, Canada (upper tree line)</td>
<td>PCGL</td>
<td>1769-1973</td>
<td>Yes</td>
<td>19</td>
<td>19</td>
<td>HEW</td>
</tr>
<tr>
<td>B-3</td>
<td>862748</td>
<td>Nain A + B, Labrador, Canada (summed)</td>
<td>PCGL</td>
<td>1769-1973</td>
<td>Yes</td>
<td>37</td>
<td>37</td>
<td>HEW</td>
</tr>
<tr>
<td>B-10</td>
<td>724</td>
<td>Novgorod Excavations, U. S. S. R.</td>
<td>PISY</td>
<td>880-1461</td>
<td>No</td>
<td>99</td>
<td>99</td>
<td>BAK</td>
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<tr>
<td>B-15</td>
<td>626399</td>
<td>Berchtesgaden High Mtns., Federal Republic of Germany</td>
<td>LADE</td>
<td>1340-1947</td>
<td>Yes</td>
<td>30</td>
<td>30</td>
<td>KB</td>
</tr>
<tr>
<td>B-17</td>
<td>290000</td>
<td>Oak West of Rhine, Federal Republic of Germany</td>
<td>QUSP</td>
<td>822-1964</td>
<td>Yes</td>
<td>270</td>
<td>270</td>
<td>EH</td>
</tr>
</tbody>
</table>
All progress in the analysis of the collections is enumerated in Table III, which lists the corrections and additions which have been made under the auspices of the current grant. This entire collection is unique in that it contains the largest amount of data as well as the greatest time depth of any tree-ring data set compiled for climatic reconstruction.

1. Eastern United States Chronologies

The subset of the above chronologies collected in the eastern United States is almost completely processed. Three new site chronologies, six computer mergers (discussed later in this report), and three summations of existing chronologies have been added to the set that was reported in Fritts et al., 1976. These additions are listed in Table III.

The eastern United States chronologies collected and processed through support of the ARPA and NSF grants as well as other eastern United States chronologies which are part of the Laboratory of Tree-Ring Research Data Base will be included in a publication to be prepared in the near future by our research group. Decisions are being made as to which chronologies should be included as part of this published set.

2. Arctic Chronologies (Wiseman)

The four collections of larch (Larix laricina) made by H. C. Fritts and J. Terasmae of Brock University, St. Catharines, Ontario, Canada, at the northern tree line near Ft. Chimo, Quebec in 1974 and dated by M. A. Wiseman (Table III) show high sensitivity to climate not only on a year-to-year basis but also over longer time periods. The index chronology derived for Ft. Chimo Site 4-L has such pronounced trends in the data—on the order of 20 to 70 years—that we decided to reexamine other Arctic materials to see if similar long-term climatic information existed in those chronologies.
The 20-year overlapping means plotted on the ring-width listing program are used to determine the internal trend agreement within a site. A tabulation is made of the high and low points on the mean curve, and a count is made for each decade of the number of high and low occurrences. The numbers are divided by the total number possible to obtain a percentage of occurrence. Only those decades that consistently exhibit peaks and troughs are tabulated as the master climatic chronology. Each measured radius is then compared to this master chronology. If peaks and troughs on a core are found in disagreement with the master set, that measured radius is either deleted as being aberrant or the trends are removed by an appropriate standardization option. Those radii following the master trends, i.e., containing the long-term climatic information unclouded by local ecological factors, are summarized with straight line or exponential curves, if such a model is appropriate.

Tabulations of trends have been completed on the Ft. Chimo sites and two other sites. These are Herring-Alpine, Alaska, collected near Prince William Sound in 1973 by Fritts and Thomas J. Sheehy of the Forest Service, Anchorage, Alaska, and Thelon Game Sanctuary, collected by J. Dennis of the National Parks Service, Anchorage, Alaska, in 1970 in the N. W. Territories, Canada, west of Hudson Bay. Trends in growth lasting for a number of decades in these two sites are not as pronounced as in the Ft. Chimo materials, but they are still apparent. We were pleasantly surprised to find most of the samples agreed on the trends indicating they were probably due mostly to climate. Computer options for the standardizing of all materials have been decided and now await computer processing. A manuscript of the full methodology and results is in preparation.
One sampled tree from Old Crow, Yukon Territory, Canada, had been contributed this autumn by Michael Church of the University of British Columbia, Vancouver, B. C., Canada, with the promise that more can be sampled during next summer's field season. The materials have been dated by Dan Duvick, and it is hoped that a chronology from this site will update the Giddings collection from the Mackenzie Delta. In addition, several cores collected from the Mackenzie Delta region by Fritz Schweingruber of the Swiss Forest Research Institute, Birmensdorf, Switzerland, have been contributed, and crossdating of these cores with the above materials is being attempted. Marion Parker of the University of British Columbia, Vancouver, B. C., Canada, reports that he also has dated cores which will be shared with us. We therefore have cancelled our plans to collect in that area.

A Quercus alba chronology approximately 100 years long has been collected for Polk County, Iowa, by Duvick. These data will be processed on grant funds and the variations related to the Des Moines, Iowa, weather record about 10 miles from the site of his chronology. If the materials are good, more collections will be needed to lengthen the chronology to make it useful for climatic reconstruction.

3. Merging of Chronologies

Six mergers of eastern United States chronologies have been added to the set of chronologies funded by Grant No. APOS 72-2406 and listed in Table III. Merging so far has been used only for sites from the eastern United States, but the procedure is applicable to any area where there are overlapping chronologies from adjacent sites. All merged chronologies are designated with an "M" as the last digit of its ID number.

The merging process as defined in this report is different than the process used in previous reports. At that time it involved only summing and averaging the two chronologies without making any adjustment for different variances. Now
the term "merge" will be used only for chronologies treated by Program MERGE or by a similar type of analysis. As of the date of this writing, all chronologies formerly designated as "merged" will be referred to as "summed." (See Tables I-III, Fritts et al., 1976.)

B. International Tree-Ring Data Bank (Sherwood)

The International Tree-Ring Data Bank (ITRDB) was established in 1974 to serve as a storehouse of high-quality tree-ring data from around the world and to make these data available to qualified scientists for the purposes of scientific research. At that time the basic organization was designed, and the minimum requirements for data entry were determined. Also, an international committee of five dendrochronologists (with H. C. Fritts, Chairman) was selected to lead the Data Bank in its future development.

Since its formation in 1974, the Data Bank has grown significantly in both the total number of entries and the basic organizational structure. While such things as the goals, standards, and format were determined at its inception, many aspects of the daily operation remained to be settled. Thus, in addition to the solicitation and receipt of contributions, recent Data Bank activity has also focused on the establishment of functional policies and procedures as well as the maximum security of all Data Bank materials. The current status of the work can be summarized as follows:

1. The Data Bank is currently accepting largely climate-related ring-width information, although arrangements are being made for the inclusion of archaeological, geological, densitometric, or other data. For the present time only contributors may request data from the Data Bank. New policies regarding the management of the Data Bank, such as those affecting the solicitation and contribution of data, requests for data, removal of a
prior contribution, security requirements, and fee schedules have been or
are being prepared and will be discussed by the ITRDB Committee at the INQUA
Congress in England this summer. In addition, the necessary papers and
procedures for routine operation have been prepared (including a new Site
Information Sheet) along with a job description for the ITRDB Manager. Also,
in the interests of increased communication among participating scientists,
the Site Information Sheet has been translated into German and French and the
Newsletter has been scheduled for publication twice annually beginning with
the most recent edition (Appendix 1).

2. The systems and programming requirements have been studied, and we are
planning for new computer software to facilitate the storage and retrieval
of the site information, ring-width measurements, indices, and other relevant
data provided by contributing scientists. Along with the systems design,
great care is being given to the precautions necessary to maintain the
long-term storage and security of all data.

3. Requirements for the acceptance of data as established in 1974 proved to be
too limiting at the present time and seriously constrained the number of
contributions which could be entered in the Data Bank. Consequently, H. C.
Fritts has authorized an additional category for data which do not meet the
original requirements. These new requirements are outlined fully in the
Newsletter (Appendix 1). Thus far, response to this second classification
has been excellent and has allowed us to accept many contributions which
otherwise would not have been available to the Data Bank. However, we hope
to eventually return to our previous more stringent requirements as more and
more scientists strive to improve the quality of their collections and results.

4. The international scope and acceptance of the Data Bank are illustrated by
the contribution of 244 chronologies representing 196 sites in 13 countries.
These contributions have been received from 20 individual scientists and one
scientific institution. In addition, the ITRDB Newsletter is read by scientists in 18 countries speaking 14 different languages.

Table IV lists only the North American chronologies that have been contributed to the International Tree-Ring Data Bank (excluding the 102 that were contributed from the tree-ring grid developed as part of the grant). While some are not the length we would like, these new collections fill areas such as Washington, Idaho, and California where there are voids in our existing network and should facilitate our particular climatic analysis by providing independent verification materials and a greater pool of data from which we can select the future expanded chronology network. We anticipate that the long bristlecone pine chronologies from both C. W. Ferguson and V. C. LaMarche, Jr., (both of the Laboratory of Tree-Ring Research) will be placed in the Data Bank and that materials from the Southern Hemisphere will be included when they are finished.

One disappointment to report is the delayed response of the Soviet scientists. So far we have received only one previously published chronology from an archaeological site. A letter was received from N. V. Lovelius of the Komarov Botanical Institute, Leningrad, in which he claimed he had not ever been informed of the agreement between the U. S. S. R. and the United States to share tree-ring materials, in spite of the fact that he and Fritts had talked about it several times. His reluctance may stem from fear of political repercussions, or there simply may be no communication in their bureaucracy. However, Teodoras Bitvinskas of the Lithuanian S. S. R. writes that they will be developing a Soviet data bank at his laboratory, although it will be a number of years before it is fully operational. He did not say they would make the data available.
<table>
<thead>
<tr>
<th>Site Name</th>
<th>Species</th>
<th>Time Span</th>
<th>Length (Years)</th>
<th>Number of Trees</th>
<th>Contributor</th>
</tr>
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<td>Santa Anna Mtns., California</td>
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<td>1671-1972</td>
<td>302</td>
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<td>A. V. Douglas</td>
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<td><em>Larix laricina</em></td>
<td>1641-1971</td>
<td>331</td>
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<td>H. C. Fritts and J. Terasmae</td>
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<td>Nain A&amp;B, Labrador, Canada</td>
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<td>H. Wright</td>
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<td>C. W. Stockton</td>
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<td><em>Tsuga heterophylla</em></td>
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<td>304</td>
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<td><em>Pinus ponderosa</em></td>
<td>1813-1975</td>
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<td><em>Pseudotsuga menziesii</em></td>
<td>1825-1975</td>
<td>151</td>
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<td>L. B. Brubaker</td>
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<tr>
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<td><em>Pseudotsuga menziesii</em></td>
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<td>L. B. Brubaker</td>
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<td>Length (Years)</td>
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<td>Contributor</td>
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<tr>
<td>Snackout Rd. &amp; Currant Creek, Washington</td>
<td><em>Pseudotsuga menziesii</em></td>
<td>1800-1975</td>
<td>176</td>
<td>11</td>
<td>L. B. Brubaker</td>
</tr>
<tr>
<td>Newport, Washington</td>
<td><em>Pseudotsuga menziesii</em></td>
<td>1807-1975</td>
<td>169</td>
<td>11</td>
<td>L. B. Brubaker</td>
</tr>
<tr>
<td>Colville Indian Res., Washington</td>
<td><em>Pseudotsuga menziesii</em></td>
<td>1791-1975</td>
<td>185</td>
<td>11</td>
<td>L. B. Brubaker</td>
</tr>
<tr>
<td>Thelon Game Sanc., Canada</td>
<td><em>Picea glauca</em></td>
<td>1574-1969</td>
<td>396</td>
<td>20</td>
<td>H. C. Fritts</td>
</tr>
<tr>
<td>Agua Fria Creek, New Mexico</td>
<td><em>Pinus edulis</em></td>
<td>1490-1972</td>
<td>483</td>
<td>12</td>
<td>W. J. Robinson</td>
</tr>
<tr>
<td>Bear Trap Canyon, New Mexico</td>
<td><em>Pinus edulis</em></td>
<td>1666-1974</td>
<td>309</td>
<td>10</td>
<td>W. J. Robinson</td>
</tr>
<tr>
<td>Hay Hollow Valley, Arizona</td>
<td><em>Pinus edulis</em></td>
<td>1687-1973</td>
<td>287</td>
<td>10</td>
<td>W. J. Robinson</td>
</tr>
<tr>
<td>Glorieta Mesa, New Mexico</td>
<td><em>Pinus edulis</em></td>
<td>1556-1972</td>
<td>417</td>
<td>12</td>
<td>W. J. Robinson</td>
</tr>
<tr>
<td>El Valle, New Mexico</td>
<td><em>Pinus ponderosa</em></td>
<td>1708-1972</td>
<td>265</td>
<td>10</td>
<td>W. J. Robinson</td>
</tr>
<tr>
<td>Jack's Canyon, Arizona</td>
<td><em>Pinus ponderosa</em></td>
<td>1534-1972</td>
<td>439</td>
<td>9</td>
<td>W. J. Robinson</td>
</tr>
<tr>
<td>Paliza, New Mexico</td>
<td><em>Pinus edulis</em></td>
<td>1658-1972</td>
<td>315</td>
<td>11</td>
<td>W. J. Robinson</td>
</tr>
<tr>
<td>Milk Ranch Point, Utah</td>
<td><em>Pinus edulis</em></td>
<td>1276-1970</td>
<td>695</td>
<td>10</td>
<td>W. J. Robinson</td>
</tr>
<tr>
<td>Site Name</td>
<td>Species</td>
<td>Time Span</td>
<td>Length (Years)</td>
<td>Number of Trees</td>
<td>Contributor</td>
</tr>
<tr>
<td>---------------------------</td>
<td>----------------------</td>
<td>---------------</td>
<td>----------------</td>
<td>-----------------</td>
<td>------------------</td>
</tr>
<tr>
<td>White Horse Hills, Arizona</td>
<td><em>Pinus ponderosa</em></td>
<td>1659-1972</td>
<td>314</td>
<td>7</td>
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</tr>
<tr>
<td>Rito de los Frijoles, New Mexico</td>
<td><em>Pinus ponderosa</em></td>
<td>1714-1972</td>
<td>259</td>
<td>14</td>
<td>W. J. Robinson</td>
</tr>
<tr>
<td>Slate Mtn., Arizona</td>
<td><em>Pinus ponderosa</em></td>
<td>1648-1972</td>
<td>325</td>
<td>10</td>
<td>W. J. Robinson</td>
</tr>
<tr>
<td>Ruidosa Ridge, New Mexico</td>
<td><em>Pinus edulis</em></td>
<td>1579-1972</td>
<td>394</td>
<td>10</td>
<td>W. J. Robinson</td>
</tr>
<tr>
<td>Ruidosa Ridge, New Mexico</td>
<td><em>Pseudotsuga menziesii</em></td>
<td>1690-1972</td>
<td>283</td>
<td>10</td>
<td>W. J. Robinson</td>
</tr>
<tr>
<td>Tajique Canyon, New Mexico</td>
<td><em>Pinus edulis</em></td>
<td>1656-1972</td>
<td>317</td>
<td>11</td>
<td>W. J. Robinson</td>
</tr>
<tr>
<td>Tajique Canyon, New Mexico</td>
<td><em>Pinus ponderosa</em></td>
<td>1691-1972</td>
<td>282</td>
<td>12</td>
<td>W. J. Robinson</td>
</tr>
<tr>
<td>Tsegi Point Rd., Arizona</td>
<td><em>Pinus edulis</em></td>
<td>1412-1972</td>
<td>561</td>
<td>12</td>
<td>W. J. Robinson</td>
</tr>
<tr>
<td>Red Butte II, Arizona</td>
<td><em>Pinus edulis</em></td>
<td>1448-1975</td>
<td>528</td>
<td>11</td>
<td>W. J. Robinson</td>
</tr>
</tbody>
</table>

NOTE: These contributions are in addition to the 102 selected chronologies (89 sites from U. S. A., six sites from Mexico, seven sites from Canada) donated by the Laboratory of Tree-Ring Research. Additional contributions have been promised by Eugene Estes of Rend Lake College, Illinois, and Marion Parker of the Forest Products Laboratory, University of British Columbia.
Contributions to the Data Bank from scientists outside the U. S. S. R. are increasing in both number and frequency, and, consequently, it is anticipated that more and more time will be required to process the data and to maintain accurate, up-to-date computer files and office records. Although the Data Bank is currently acting only as a repository for data, it is expected that the growing interest soon will generate inquiries and requests for data which will also require prompt and efficient handling. The management of all Data Bank materials and the publication of the second issue of the Newsletter will be among the expanding responsibilities of the Data Bank Manager in the months to come. The typist position will be expanded from half-time to full-time to help carry the increased data bank activity.

C. Laboratory of Tree-Ring Research Data Base (Robinson)

Although we still have just received the supplemental funding for this particular project, a committee which is headed by W. J. Robinson and which includes H. C. Fritts, Linda G. Drew, Judith Sherwood, and Donald Stevens, is meeting weekly to plan future work and strategies. Efforts have been directed primarily toward the creation and improvement of internal management records. To this end, we have formalized a job description for the Data Base Manager and have developed working documents for the data entry categories, the site information record for chronologies, and the site information record for weather records. We have not yet considered the problems involving file creation for reconstructions.

The work of building up our chronology files is being carried forward on state funds by Linda G. Drew, who heads the data processing section, and her staff. In the near future, we expect to employ a Data Base Manager who will take over most of the daily problems of development of the management system. We will also begin work in software development.

Because of the large size of these particular collections and the need for
continuing support for this important archival program, we are hoping to find appropriate funding separate from commitments to a specific research activity.

D. Experiments with Different Tree-Ring and Climatic Grids (Conkey)

The Arizona grid project and the Shatz study described in earlier reports were designed to test our methods using smaller sets of data as predictors and predictands. The backgrounds and the reasons behind the two projects were different, so they are treated separately in this report. This work is presented in detail here to illustrate how one student in the research group has experimented with the methods, partly to become acquainted with the techniques, and partly to explore the limits of the systems used in the analysis.

1. Arizona Grid

This project was begun as a class research problem in the use of canonical correlation using a selected set of 60 chronologies (called the greater Arizona subset of the larger western North American grid) and climatic data from weather stations in and around Arizona. A double-mass analysis was run on the precipitation records with other records in the vicinity. After careful study and analysis, the following climatic grid was chosen:

- Clifton, Arizona
- Douglas Smelter, Arizona
- Flagstaff, Arizona
- Holbrook, Arizona
- Phoenix, Arizona
- Pinal Ranch, Arizona
- Tucson, Arizona
- Walnut Grove, Arizona
- Yuma, Arizona
- Cuyamaca, California
- Needles, California
- Cañon City, Colorado
- Bloomfield, New Mexico
- Fort Bayard, New Mexico
- Moab, Utah

The precipitation data were summarized into seasons: spring (March through June), autumn (July through October), and winter (November through February). Ten principal components were extracted for each of the three seasonalized data sets. This cutoff included a number of small-scale eigenvectors (with a small signal-to-noise ratio), but it was felt that by using less than 10, we would greatly reduce
the number of canonical sets possible. There was no such problem with the tree-
ing eigenvalues; 10 eigenvalues out of a possible 60 kept us well above the noise level. The calibration period was 1910 to 1963, and the model chosen for all three seasons was 10r10c, or 10 tree-ring principal components to predict 10 precipitation principal components.

The job stream calibration program (now called REPACK) was run on each season. The results for spring did not show any clear-cut pattern, and no canonical weights were greater than 0.64. Only 19% of the climatic variance was calibrated by the four significant canonical steps that entered into the equation. Comparisons between actual and reconstructed values for the calibration period were not very successful, with only 11 of the 54 years showing a correlation higher than 0.60. Therefore, the decision was made to go on to autumn without trying to verify the spring reconstructions on independent data.

The equation for autumn also calibrated only 19% of the climatic variance with three canonical correlations entering into it. Only three years of the 54 in the calibration period correlated better than 0.60.

In winter, a season of more consistent meteorological conditions throughout the area, the canonical equation reconstructed 30% of the climatic variance, which was a definite improvement over the other two seasons. Only 13 of the 54 calibrated years showed a correlation better than 0.60 between the actual and the reconstructed values. Nonetheless, the percent variance reduced was sufficiently encouraging to test verification on independent data.

A final calibration model was tried with REPACK, again using the winter months of precipitation values. The tree-ring series was lagged by one year using 10 principal components of the current year of growth (year t) and 10 principal components of the year following (year t+1) to estimate the climate of year t. The model is 10c10i10f. This equation calibrated 40% of the variance, although only two canonical correlations entered into it, the second just barely
passing the F-test (where $F > 1.86$). The low F-values reflect the more rapid consumption of degrees of freedom with the addition of 10 more predictor variables than in the nonlagged model, and for this reason it was hypothesized that the reconstructions would not hold up in verification attempts using independent data.

At this point, a talk was prepared and presented to members of the American Quaternary Association at their biennial meeting field trip in the San Francisco Peaks near Flagstaff, Arizona (Oct. 6-10, 1976). The talk was designed to acquaint the group with the concepts of dendroclimatological research using a specific study dealing with the local environment and did not try to give definitive results.

Although the percentage of climatic variance calibrated by the canonical correlation was not very high (30%), the nonlagged winter model (10r101) was chosen for verification with program REVAR as it was thought to be most stable. The winter precipitation reconstructions were run through REVAR with seasonalyzed precipitation records previous to 1910. The amount of additional data available varied from station to station, depending on how long consistent records had been kept.

Only four stations passed enough tests to be considered highly significant reconstructions: Clifton, Holbrook, and Walnut Grove, Arizona; and Fort Bayard, New Mexico. Others (Douglas Smelter, Pinal Ranch, Tucson, and Yuma, Arizona; and Cañon City, Colorado) passed one of the four crucial tests. The remaining six stations did not pass any of the verification tests, and their reconstructions must be used with caution depending upon what other types of verification can be made for the reconstructions. These results are comparable to the results reported earlier for the Shatz experiment and are similar in degree and number of verification to the results from the larger United States grid of 78 climatic stations.
2. Shatz Experimental Grid

A comparison of stepwise multiple regression and canonical correlation begun by Shatz is described in the Final Technical Report, Grant No. AFOSR 72-2406 (Fritts et al., 1976) and in the Progress Report and Proposal, Grant No. ATM75-17034 (Fritts, 1976a). This study was continued with a new canonical analysis using different data. The predictor set from Shatz's 10-station tree-ring grid was changed to the wider area 65-tree-ring chronology grid using the first 10 eigenvector amplitudes of this set of the 32 randomly chosen years as tree-ring predictors. The predictand set remained as Shatz's 32 randomly chosen years of data from 10 stations. These data were seasonalized and efforts were concentrated on spring (March through June). Mindful of the problems encountered in the Arizona grid project of mixing raw data with principal components, a principal components analysis was run using the spring precipitation records of the 32 calibration years. This was done primarily to facilitate data handling in REPACK, and all 10 resulting eigenvectors were used in the analysis, including all the original data rotated into orthogonal modes of behavior. The model for the REPACK run was 10r10i, the same used in the Arizona grid.

Four canonical correlations entered into the equation calibrating 37% of the variance with an F-level of 2.537. Twelve years of the 32 in the calibration period showed a correlation of greater than 0.60 between the actual and the reconstructed years. This is a higher percentage of success than any of the Arizona grid reconstructions, and the percent variance calibrated is higher than both the Arizona grid results and the results of Shatz's previous calibrations. However, there were many fewer degrees of freedom. It was then important to test how well these results would be sustained by the independent verification
using the 20 years from in and around the 32 randomly selected years used for calibration.

Because the years of dependent and independent data were discontinuous, REPACK could only reconstruct for the calibration period. The reconstructing canonical equation was used to generate reconstructed precipitation values for the desired independent years. These were then run through REVAR, the verification program, to compare them with the actual precipitation values for the 20 years of independent data. None of the stations passed the test for verification as well as those in Shatz's earlier study, and only two of the individual tests were passed, a very poor showing.

Shatz's station-on-station regression analysis calibrated 28% of the variance, and some of the stations were sustained by independent data. The analysis described here using a larger predictor set calibrated 37% of the climatic variance but did not hold up in verification. This does not necessarily indicate the superiority of simple regression over canonical analysis for this type of study, but it does indicate that regression statistics on the calibration period are not reliable measures of the reconstruction validity. We concluded that the climate data base here was probably too small with too short a record and that station locations were too widely scattered for a successful canonical analysis. Also, we had used too many degrees of freedom and included too much noise in the analysis, so noise was reconstructed. We will discontinue the the Shatz study as a poorly designed experiment with too short an interval for calibration and for testing canonical versus multiple regression analysis. In Section IIIF of this document, Blasing reports a new study using longer records of crop yields in which results from both of these two techniques are compared.
A master's thesis project is underway to apply dendroclimatic principles and practices to areas outside of the dry western North American region. This work involves a number of already collected and processed tree-ring sites in the northeastern United States. Results of the response functions were reported in the Progress Report and Proposal, Grant No. ATM75-17034 (Fritts, 1976a) for the following sites: Camel's Hump, Vermont; Nancy Brook, New Hampshire; and Livingston, Massachusetts. Since then permission has been obtained to use four sites in the Mohonk Lake region of New York which were analyzed by Edward R. Cook, now of Lamont-Doherty Geological Observatory, Palisades, New York. He has already run response functions on these sites, and the results are included in his unpublished master's thesis (Cook, 1977).

A new chronology was produced by summing the two subsites at Camel's Hump using Site A plus Site C (dropping the less sensitive, shorter series of Site B). Response functions will be run for comparison to A + B + C and to the other New England sites. Another *Picea rubens* site to be included is at Giant Ledge, New York, collected by Thomas Siccama of the School of Forestry and Environmental Studies, Yale University. We would like to run more response functions using different monthly combinations for comparison and new climatic data. The data used previously (from the Weather Bureau's decennial census) have drawbacks in their conglomerate nature, e.g., the stations become more numerous, especially from the more remote areas, through time.

A search for good climatic records to use in the calibration and reconstruction of New England climate has been initiated. Historians Dave Smith and Bob Baron at the University of Maine, Orono campus, have been researching historical climate sources, and these are available courtesy of Hal Borns and Wibjörn Karlén, also of the University of Maine. We are also searching for other long, homogeneous records to use in analysis. Similarly, literature research is underway for
good discussions of the ecological and climatological nature of coniferous forests in the northeastern United States to aid in the model building and response interpretation.

Two sites in north central Maine were collected this summer. Dating has been obtained for these materials, but the cores are too short for use in climatic reconstruction. More sampling is planned this summer to be supported at least in part by the University of Maine's Institute for Quaternary Studies.

A complete report on this project has not yet been prepared, as the work is just commencing, but a proposal for the master's thesis has been submitted entitled "Dendroclimatology in the northeastern United States." This thesis, and therefore the work on this aspect of the project on eastern dendroclimatology, is to be completed by summer, 1977.

F. Continuing Experiments in Reconstructing Crop Yields (Blasing)

The techniques developed for reconstruction of climate from tree rings can also be applied to reconstructing phenomena such as drought, streamflow, potential energy consumption, fluctuations in animal populations, forage production, and crop yields, because these phenomena are influenced by the same climatic factors as is the growth of trees. Thus, the short record of agricultural production can be extended into the past by use of tree rings. This extended record is then available to measure the long-term attributes of the crop-climate system and to estimate the likely effects of future climatic variation on related activities of man.

Past exploratory work using crop data has been undertaken by several members of our staff. Recently we obtained crop information published by the Institute of Ecology (1976) on United States corn, sorghum, soybeans, and wheat, along with Canadian wheat. We also have consulted with Darell McCloud of the Agronomy Department, University of Florida, who developed these data, and for the first
test have accepted his removal of technological trend. A polynomial curve was fitted to the data as a function of time with the residuals from this curve portraying the effects of climate on the yearly crop production.

Multiple linear regression was used to estimate yields of these crops (in bushels per acre harvested) using the first 15 eigenvector amplitudes of ring width for the same growing season (from the 65 tree-ring chronology grid) as predictors of yield. The calibration period common to the crop and tree-ring data consisted of the 35 years from 1929 to 1963 inclusive. The data prior to this interval, which in the case of United States wheat and corn extend back to 1866, were used for verification testing. We also applied canonical regression to the same data, but the tests on independent data using this method of calibration have not been completed. The results obtained so far are tabulated in Table V.

All of the correlation coefficients for the calibration period are significant, and those obtained in the independent period are positive, but only the one for United States wheat is significant at the 95% confidence level. Further analysis indicated that while increases or decreases in yield are often correctly specified, the mean yield values over the entire independent data period are consistently off. Possible reasons for this include: 1) too short a calibration interval, 2) weak or nonexistent relationships involved, 3) problems with the technique of multiple linear regression, and 4) problems with the trend-fitting procedure for crop data. The correlation coefficients for the independent data period, especially for United States wheat, suggest that some real relationships exist and that some combination of the first, third, and fourth reasons may be responsible for errors in estimating long-term mean yields in the independent data period.
### TABLE V

**Results of Crop Yield Reconstructions**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Percentage of variance calibrated</th>
<th>Correlation coefficient between predicted &amp; actual data (calibration period)</th>
<th>Correlation coefficient using independent data</th>
<th>Number of years of independent data</th>
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</thead>
<tbody>
<tr>
<td>U. S. corn</td>
<td>47 (19)</td>
<td>+.69 (+.44)</td>
<td>+.16</td>
<td>63</td>
</tr>
<tr>
<td>U. S. sorghum</td>
<td>63 (71)</td>
<td>+.79 (+.84)</td>
<td>none</td>
<td>5</td>
</tr>
<tr>
<td>U. S. soybeans</td>
<td>17 (12)</td>
<td>+.41 (+.35)</td>
<td>+.64</td>
<td>63</td>
</tr>
<tr>
<td>U. S. wheat</td>
<td>34 (24)</td>
<td>+.58 (+.49)</td>
<td>+.44</td>
<td>8</td>
</tr>
<tr>
<td>Canadian wheat</td>
<td>29 (51)</td>
<td>+.54 (+.71)</td>
<td>+.80</td>
<td></td>
</tr>
</tbody>
</table>

**NOTE:** Numbers in parentheses pertain to canonical regression, others to multiple linear regression.
We plan to carefully compare canonical regression to multiple linear regression as in the studies reported by Conkey to see if one reconstruction is better than the other, especially for the independent data prior to 1929. If verification is significant, then the potential crop production will be estimated back to 1601 to assess possible periodicities and to measure anomalies from various periods often used to determine climatic norms. Such an approach can serve as a check of the revived hypothesis that the sunspot cycle can be used to anticipate what future crop yields may be.

Another test of the same hypothesis was made using our temperature and precipitation reconstructions west of the Mississippi River. C. W. Stockton had calibrated the Palmer Drought Severity Indices for a number of regions over the same area with a set of tree-ring chronologies similar, but not identical, to ours. When he tabulated his reconstructions as the number of stations with a Drought Severity Index below a critical value, he obtained a time series that was apparently related to the 22-year sunspot cycle.

We tabulated our data in a similar fashion combining the number of stations reporting below-average precipitation with the number of stations reporting above-average temperatures for the spring season. Stockton compared our two series and reports substantial coherency between our two sets of data in the 1/22-year frequency, although its significance has not been tested. Because of this encouraging result, we are making a number of calibration runs with his Palmer Drought Severity Indices using our computer software. We have applied our tree-ring set and a model resembling the one Stockton used in his analysis to evaluate any differences in the reconstruction due to differences in the tree-ring grids. We calibrate 53% of the drought severity indices for 1930-1967. Working with Stockton we plan to vary the models to see if there is any substantial improvement of the calibration statistics and to compare the various results in terms of the 22-year periodicity. We then plan to use our verification
program to examine and test each of the reconstructions for the independent period. Stockton has calculated drought severity indices for a new grid of single stations in order to establish a longer calibration interval covering most of the twentieth century. When he is satisfied with the new grid, we will work with him on the subsequent calibrations.

These analyses are being conducted jointly, and the results will be shared by both Stockton's and our research teams. We are primarily interested in the drought severity reconstructions as an additional parameter to be associated with the pressure reconstructions and the detailed climatic chronology which we are assembling. Therefore, Stockton will assume the final responsibility for establishing their validity and their eventual publication.

G. Climatic Typing (Lofgren)

Starting with the work of Blasing (1975a and b) and Blasing and Fritts (1976), a method was developed for characterizing climate anomaly types using spatial correlation techniques. The original work has been expanded to include the climatic record from 1899 to 1971.

A set of from five to six pressure anomaly type patterns has been derived for each of four seasons, and the corresponding anomalies of mean temperature, total precipitation, and tree growth have been identified. Twenty-one figures which characterize each type are now drafted and assembled for final reporting. The five types for winter are included in Figures 2-6.

The 700 mb isobaric surface heights from December, 1946, through February, 1976, have been acquired, and a portion of these data has been analyzed. Since some of the types occurred primarily before 1946, we reconstructed the short 700 mb surface record back to 1899 by calibration with the surface pressure data. These reconstructions have been used by Marna Ares in conjunction with the actual upper-air data to define 700 mb height anomaly patterns associated with the surface pressure types.
Figure 2. Winter pressure anomaly Type 1 and the corresponding anomalies in temperature and precipitation.
Figure 3. Winter pressure anomaly Type 2 and the corresponding anomalies in temperature and precipitation.
Figure 4. Winter pressure anomaly Type 3 and the corresponding anomalies in temperature and precipitation.
Figure 5. Winter pressure anomaly Type 4 and the corresponding anomalies in temperature and precipitation.
Figure 6. Winter pressure anomaly Type 5 and the corresponding anomalies in temperature and precipitation.
Katherine Hirschboeck utilized the file of the Dzerdzeevskii circulation mechanisms supplied by Wahl at Wisconsin and the program developed by Stevens to relate each pressure anomaly type to specific sets of the Dzerdzeevskii types. This work involved the reclassification of the Dzerdzeevskii types into a simpler set of nine types representing the main features of the Northern Hemisphere grid used for defining Blasing's pressure anomalies. A complete description of this work is on file, and the final results will be incorporated in a manuscript being prepared by Lofgren and Blasing.

Other data that we hope to use in the characterization of the climatic types are: a) the Krück-Elliott synoptic climatic types, b) sea surface temperatures (provided by Jerome Namias of Scripps Institution of Oceanography), and c) the Palmer Drought Severity Indices. Results of the study for winter and summer are being prepared in a manuscript by Blasing, Kutzbach, and Fritts.

Climatic types have become an exceedingly valuable tool for simplifying the characterization of past climatic variability, for comparing the reconstructions from different calibration models, and for calculating the expected probabilities of future variations in climate. In addition, we have developed a program that examines the occurrences of each type for each season for a particular length of record and then calculates the expected frequencies in preceding or subsequent seasons given a particular type occurrence.

Another study has just been initiated with W. D. Sellers of the Institute of Atmospheric Physics, University of Arizona, in which we are examining other possibilities for climate predictability using lagged correlations of our existing reconstructed and actual 700 mb data grids. The principal components of the 700 mb record back to 1900 can be estimated by multiple regression on the principal components of the 700 mb record for prior seasons and the reduced variance tested for significance. Our part at present is to assist Sellers with the use of our data and programs. Future directions will depend
in large part upon what aspects of the preliminary screening work prove to be significant and upon how well other reconstructions are verified by independent data sets.

H. Assessing the Value of Densitometric Data from Swiss Alpine Trees (Fritts)

Dr. Fritz H. Schweingruber of the Swiss Forest Research Institute, Birmensdorf, Switzerland, worked with us from August 23 to October 23, 1976, under a grant from the United States National Academy of Sciences. He brought data from 37 different tree stands which had been processed through x-ray density analysis so that measurements were available on ring width, earlywood width, latewood width, maximum density, and minimum density making a total of 185 different chronologies. The total collection contained a larger number of chronologies than we had expected, but the individual chronologies were considerably shorter and less well replicated than chronologies used in our work. Consequently, the study was considered to be a feasibility study to demonstrate what can be done and to encourage Europeans to become more involved with climatic reconstruction work.

Although all of Schweingruber's expenses, including most of the data processing, were covered by the grant from the National Academy of Sciences, we could not have undertaken the endeavor without the compatible and flexible set of programs produced on this and earlier grants and the availability of research staff to assist in the processing and interpreting work. It is reported here because time and assistance with program operation were partly borne by the National Science Foundation grants. It also represents an example of international cooperation made possible by the flexibility built into our present program.

All 185 chronologies were processed using the standard methods. The Swiss climatic data were double-massed or first-differenced to identify station moves and nonhomogeneous records. Response functions were run on the better chronologies
and revealed that summer temperature was the most important limiting factor. Maximum density proved to be the best climatic predictor.

Several transfer functions were derived using an ensemble of tree-ring data as predictors (first density measurements and then density plus all other factors including ring width) and July-August temperatures at four stations as the predictands. A transfer function using the density calibrated 65% of the total temperature variance, but when both ring width and density data were used, 71% of the variance was calibrated. These reconstructions were then tested with independent climatic data prior to the interval used to calibrate, and the results were highly significant. Thus, we concluded that maximum density data from the less stressful sites of Europe (and probably eastern United States) are excellent indicators of summer temperature.

This is the first conclusive test of x-ray density data from Europe used in a response and transfer function analysis. It confirms earlier work which suggested that in moist areas such as central Europe, x-ray density data is a better predictor of climate than ring width. However, density data is much more difficult to obtain than ring-width data and therefore may be more costly to work with than ring widths.

I. Ring-Width Standardization Procedures (Fritts, Winter, and Lofgren)

Our last progress report described investigations of a new standardizing procedure suggested by Ernst Hollstein of the Rheinisches Landesmuseum Trier, Federal Republic of Germany. After careful study, it became apparent that Hollstein's procedure and our standard exponential method of standardizing ring widths are very similar, and under certain boundary conditions, identical. Since there was no advantage to his method, we have abandoned this particular effort. The mathematical proof of the similarity in the methods is on file.
J. Travel

H. C. Fritts visited the People's Republic of China as part of a University of Arizona delegation from June 14 through July 2, 1976. A preliminary report, submitted to the National Science Foundation on November 1, 1976, describes two meetings with Chinese tree-ring workers in the Academy of Science, Peking. Discussions in the first meeting centered around the Chinese program. The second meeting featured a talk by Fritts describing our climatic reconstruction program. The Chinese informed us that a request was being made to their government for permission to collaborate with University of Arizona dendrochronologists. Subsequent correspondence continues to be friendly, but permission for further collaboration has evidently not yet been granted. Travel by Fritts is planned in the summer of 1977 to work on the Data Bank and to participate in two dendrochronological programs: 1) the Symposium on the Dendrochronology of Northern Europe (July 11-14) in Greenwich, England, and 2) the Tenth INQUA Congress (August 16-24) in Birmingham, England. During the period between these two conferences, Fritts will work with scientists in Belfast, Liverpool, and especially with the Climatic Research Unit at the University of East Anglia, Norwich.

Other meetings attended by research personnel since the last progress report are listed as follows:

   
   Attended by H. C. Fritts who presented a paper entitled "The Use of Tree-Ring Chronologies to Estimate Past Climate."

2. Second Ecology-Meteorology Workshop sponsored by the Energy Research and Development Administration, August 16-20, 1976, University of Michigan Biological Station, Pellston, Michigan.
Attended by H. C. Fritts who was a member of the panel on "Biological Indicators of Climate Modification."

   Attended by H. C. Fritts who presented a paper entitled "Characteristics of Tree Rings as Predictors of Climate."

   Attended by T. J. Blasing and H. C. Fritts who presented a paper entitled "Climatic Variations Reconstructed from Tree Rings" by H. C. Fritts, T. J. Blasing, and G. R. Lofgren.


Abstracts:

"Tree Rings as Indicators of Climatic Changes Involving Deserts," by T. J. Blasing.

"Reconstructing Climatic Variability over North America for the Last Several Centuries," poster display by H. C. Fritts, T. J. Blasing, and G. R. Lofgren.

"Pattern of Climatic Anomaly over North America and the North Pacific during the 20th Century," poster display by G. R. Lofgren and T. J. Blasing.

"Dendroclimatic Inferences from Fort Chimo, Northeastern Canada," by M. A. Wiseman and H. C. Fritts.

Attended by H. C. Fritts, T. J. Blasing, and G. R. Lofgren.

Poster Displays:


Attended by G. R. Lofgren and M. C. Ares.

Abstracts:

"Reconstructing Climatic Variability over North America and the North Pacific for the Last Several Centuries," poster display by H. C. Fritts, T. J. Blasing, and G. R. Lofgren.

"Pattern of Climatic Anomaly over North America and the North Pacific during the 20th Century," poster display by G. R. Lofgren and T. J. Blasing.


To be attended by L. E. Conkey and T. J. Blasing.

Abstracts:

"Mapping Past Climates from Tree-Ring Data," poster display by H. C. Fritts, G. R. Lofgren, and T. J. Blasing.

"North American Climatic History as Inferred from Tree Rings," by T. J. Blasing.
IV. SUMMARY AND SIGNIFICANCE OF THIS WORK

This section summarizes the status of the work on these two projects and includes an example of how we expect to apply the results to problems of national need.

A. Summary of Most Significant Results on Grant No. ATM75-17034
(Applied Research Reconstructing Past Climate of the Northern Hemisphere by Use of Tree Rings)

1. The chronology collection and development, which were initiated as an ARPA project (ARPA Grant No. AFOSR 72-2406) and continued under this grant, have resulted in a set of 111 separate high-quality chronologies from the contiguous United States and nearby areas of Mexico. A subset of these chronologies is part of a grid of 102 selected chronologies from western North America which has been published and is now being used extensively for climatic reconstruction (Drew, 1976). All chronologies in this grid have been contributed to the International Tree-Ring Data Bank.

More than 17 chronologies from throughout North America have also been collected and/or processed in various ways by personnel on this grant. Of special importance are two new chronologies from the contiguous United States and Mexico, three high-quality Arctic chronologies reexamined and reported by Wiseman, and some new materials examined by Duvick. When processing is completed, all of these data will be useful for independent climatic verification work and will become a resource for expanding the selected grid mentioned above to eastern North America and to the Canadian-Alaskan Arctic. The Laboratory of Tree-Ring Research Data Base and the International Tree-Ring Data Bank will also facilitate the eventual expansion of these grids to world-wide coverage.

2. International collaboration which was reported in the first progress report as well as this document involved H. Burghart Schmidt, Köln, Federal Republic of Germany; Barbara Gray, Climatic Research Unit, Norwich, England; and Fritz
Schweingruber, Swiss Forest Research Institute, Birmensdorf, Switzerland. Others such as W. E. S. Henoch of the Inland Waters Directorate, Ottawa, Canada; Marion Parker and Michael Church, both of the University of British Columbia, Vancouver, B. C., Canada; Eugene Estes of Rend Lake College, Ina, Illinois; Harold Borns at the University of Maine, Orono, Maine, are presently working with us on extending the collections in the American Arctic and eastern United States.

3. Data retrieval and analysis programs are now available for data manipulation, mapping and plotting, and hypothesis testing.

4. A variety of applications have been identified, and the following results are reported:

a. Our present tree-ring standardizing procedure cannot be improved using the methods proposed by Hollstein, as we had thought earlier. The two methods are essentially the same.

b. Crop data can be calibrated with tree-ring data, and the reconstructed record appears valid when compared to independent data. We plan to examine the possible use of reconstructed crop records and other similar data in terms of agricultural planning.

c. Sets of climatic pressure anomaly types are defined for each of the four seasons, and we are using them to characterize past climatic reconstructions and to estimate the expected probabilities of climatic occurrences in the future. (See Section IVB for details of this application.)

d. A tentative examination of Stockton's 22-year sunspot-tree-ring linkage is encouraging, but final conclusions depend upon results that are now being computed.
e. *Tree Rings and Climate*, a 567-page book by Fritts, has been published. It summarizes the current status of the field and reports many early results from the two projects.

f. Inquiries regarding past climate are increasing, and we are treating the most relevant ones as our resources and staff allow. We are now keeping records of all such inquiries, and in the future we will attempt to report on the total number with details on those most relevant to our climatic reconstruction efforts.

B. Summary of Most Significant Results on NSF Grant No. ATM75-22378 (Climatic Variations for North America and the North Pacific Since A. D. 1500 as Identified by Well-Dated Tree Rings)

1. We are becoming confident that our reconstructions of pressure, temperature, and precipitation from ring-width variations are based upon the optimum linear models available with our present data sets and technology. As reported in our 1976 progress report, there are real and significant relationships among pressure, temperature, and precipitation. Also, tree-ring variation throughout western North America is a reasonable proxy of all three parameters of climate. At present, the highest calibrated pressure variance (averaged over the entire grid) ranges from 40.5% for both summer and autumn to 43.0% for spring. If we confine the analysis to the eastern North Pacific and North American continent, the reconstructions account for as much as 50-70% of the pressure variance throughout a large part of the grid. The maximum variances calibrated for temperature thus far range from 33.8% for autumn to 47.9% for summer. Only 30% of the precipitation variance is reduced indicating the weakest overall statistical linkage (probably due to the low spatial coherency of this variable). We have also combined the reconstructions for two or more models and increased the percent variance calibrated. For example, for two winter pressure models the percent variance calibrated was 29.8% and 41.7% for the
individual models and 43.9% for the combination. At present 169 models out of approximately 270 are fully calibrated. Reconstructions go back to 1600 and are accessible from magnetic tape for analysis.

2. We are also confident that our methods for selecting the best statistical models are objective, rigorous, and effective. They include verification tests of independent temperature and precipitation, comparisons among the available reconstructions, as well as comparisons of actual and reconstructed data for the dependent period of calibration. While much of this work is now in progress, we expect to finish a large part of it, except for independent verification, by the termination date of this particular grant.

3. The verification checks using independent data which have just begun appear to provide the best and most reliable tests of reconstruction reliability.

4. Attention is now being directed to characterizing past variations in climate. Our initial step is to map past climatic variations by 50-year intervals starting with the seventeenth century. Pressure, temperature, and precipitation anomaly maps are being constructed from the best models. Time series are also being plotted using various regional averages (Fig. 7) or pressure gradient representations. Frequencies of occurrences of climatic types are also being computed and plotted.

In addition, we plan to divide the continuous reconstructed record into smaller periods with similar climatic variation using the typed frequencies to recognize the inhomogeneities. Eventually, we plan to map seasonal data for each year, to contour them, and to copy the maps on microfilm using a facility like the NCAR computer.

C. An Illustrative Study of a Particular Climatic Variation: The Winter of 1976-77

This winter's climate is characterized by remarkably cold temperatures in the eastern United States and drought throughout the central and western portions
Figure 7. Time series plots for actual and average reconstructed winter temperatures at eight stations in California. Plot C includes the yearly reconstructions with the 0.95 confidence intervals and plots A and B show the same data using a low-pass filter. Data were verified using Roden (1966).
of the continent. We examined our accumulated data to see what could be said about the frequency of past climatic occurrences resembling this winter's climate. The temperature pattern for the winter of 1977 resembled our winter pressure anomaly Type 5 (Fig. 6). The only other winter type to bring cold to the East was our Type 3, which was associated with cold weather in the North and Northeast (Fig. 4). The other three winter types were dissimilar, as they brought mild conditions to the East and/or cold to the West (Figs. 2, 3, and 5). We therefore examined our best pressure reconstructions for the occurrences of Types 3 and 5 versus Types 1 and 2 (Fig. 8 and Table VI).

The reconstructed occurrences of each pressure anomaly type (with \( r^* > 0.3 \)) were counted. The reconstructed occurrences for the twentieth century were compared to the actual occurrences to obtain the overtyping (or undertyping) ratio as described earlier, and the reconstructed frequencies were multiplied by this ratio to adjust the reconstructions in proportion to the actual differences observed for the calibration years. The results for two of the best models are included in Table VI.

It can be seen from the table that for 1900–1970 the cold types (3 and 5) occurred at a frequency of 29.7%, but in the past they occurred 50.6% or 20.9% more frequently. The warm Types 1 and 2 were more frequent in 1900–1970 (47.9%) but occurred 19.8% or 27.6% less frequently in the past. If we average the two intervals together, we obtain the optimum expectation for the types because they are based upon the largest sample, a 370-year interval of time. The two cold types for the eastern United States would be expected to occur 46.6%, or about one year in two. The expectation for the warm types (in the eastern United States) is half that of the cold types (25.7%). The remaining expectations are the average conditions or years with variable climatic anomalies that resembled none of the five types. Appendix 2 is a news release describing these
Figure 8. The occurrences of winter types for the last four centuries as reconstructed from the 15115m model. Longer bars indicate that the correlation with the type was $\geq 0.3$ and, hence, significant. These data are tabulated to derive the long-term probabilities.
### TABLE VI

Summary of Percentages of Occurrence of Types and Combinations
Of Types Using Reconstructions from Two Calibration Models
For 1601-1899 and Actual Climatic Data for 1900-1970

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Time Period</th>
<th>Types</th>
<th>Combinations</th>
</tr>
</thead>
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<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Model 10p15i5m</td>
<td>1601 - 1899</td>
<td>15.2</td>
<td>5.0</td>
</tr>
<tr>
<td>Model 10p10i10m10f</td>
<td>1601 - 1899</td>
<td>15.5</td>
<td>4.9</td>
</tr>
<tr>
<td>Average of Models</td>
<td>1601 - 1899</td>
<td>15.4</td>
<td>5.0</td>
</tr>
<tr>
<td>Climatic Data</td>
<td>1900 - 1970</td>
<td>25.4</td>
<td>22.5</td>
</tr>
<tr>
<td>Difference</td>
<td>1601 - 1899 - 1900 - 1970</td>
<td>-10.0</td>
<td>-17.6</td>
</tr>
<tr>
<td>Average</td>
<td>1601 - 1970</td>
<td>17.3</td>
<td>8.4</td>
</tr>
</tbody>
</table>

---Prepared by H. C. Fritts
February 1, 1977
results prepared jointly by the NSF public relations office and by our staff.

We are not restricted to the above frequency study for such an analysis. We can also check results by examining the averages of the temperature and precipitation reconstructions which were calibrated independently of the pressure reconstructions used in the typing. The results from the best temperature and precipitation models were averaged by station for the 1601-1900 interval by program DIFFMAP and the data plotted as departures from the 1901-1965 averages (Fig. 9 and 10). We also plotted the departures for the period 1601-1650 to test for differences in the middle of the Little Ice Age or Neoboreal period (Figs. 11 and 12). Pressure anomalies reconstructed for the same intervals are presented in Figures 13 and 14. The results confirm the earlier conclusion that the past three centuries were generally colder in the eastern and northern United States and somewhat warmer than the modern norm in the West. Precipitation was below normal for large areas of the Country. California was drier than the modern period, but the Pacific Northwest was near the modern mean with more moisture in the northern Rocky Mountains. The eastern seaboard and Gulf states were near average or moist.

Using Program TYPSEQ described earlier, the occurrences of types in the actual surface pressure record were also examined to ascertain the likelihood that a Type 5 winter is preceded by or followed by other seasonal types. The results are shown in Table VII. Although Type 5 winters occurred only nine times during the 72 years studied (so the results are not conclusive), the table suggests a predictive possibility for winter Type 5 using summer types and winter Type 5 as predictors. Summer Types 1, 5, and 6, all drought types, preceded winters like 1977 eight out of nine times and followed winters like 1977 seven out of nine times. The summer of 1976 was indeed dry over the northern and central plains
Figure 9. Average winter temperature reconstructed for 1601-1900 expressed as departures in standard deviation units for the period 1901-1965. The model used was 7t15b151.
Figure 10. Average winter precipitation reconstructed for 1601-1900 expressed as departures in standard deviation units for the period 1901-1955. The model used was 15r15i15m.
Figure 11. Same as Figure 9, except for 1601-1650.

1601-1650 WINTER TEMPERATURE

78 Stations
30 Significant
1601-1650 WINTER PRECIPITATION

Figure 12. Same as Figure 10, except for 1601-1650.
Figure 13. Average pressure anomalies reconstructed for 1601-1900 expressed in millibars as departures from the 1899-1971 mean.
Figure 14. Same as Figure 13, except for 1601-1650.
TABLE VII

Frequency of Occurrence of Seasonal Types Preceding and Following a Winter Type 5 (Winter of 1976-1977) Based on Nine Occurrences in Twentieth Century Data

<table>
<thead>
<tr>
<th>Seasonal Type Preceding</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
<th>Autumn</th>
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<tr>
<td>1</td>
<td>3</td>
<td>4</td>
<td>3</td>
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</tr>
<tr>
<td>6</td>
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<td>2</td>
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<table>
<thead>
<tr>
<th>Seasonal Type Following</th>
<th>Spring</th>
<th>Summer</th>
<th>Autumn</th>
<th>Winter</th>
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<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>1</td>
<td>6</td>
<td>2</td>
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<tr>
<td>2</td>
<td>1</td>
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<td>0</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
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<td>1</td>
<td>0</td>
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<tr>
<td>4</td>
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</tr>
<tr>
<td>6</td>
<td></td>
<td>1</td>
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</table>
and the Great Lakes region (like Types 1, 5, and 6), and our data suggest that there is a seven out of nine likelihood that next summer will be dry also. We recognize that these remarks are little more than speculation at present, but we believe our reconstructions can be examined in a similar way to increase the sample size of the probability estimates and perhaps to better define a possible relationship which might be useful in the future for prediction purposes.

Time series of regional averages were also constructed from data grouped into geographical regions, and plots of climatic anomaly have been produced for further study (Fig. 7).

These averaged series were then correlated with the average of the actual data from the same region. In addition, the series were treated by high- and low-pass digital filters and correlated. Table VIII includes the square of the correlation coefficients. In general, the percent correlated variance (correlation squared) was lower for the individual stations than for the regions. The higher correlations squared for the low-pass filtered set indicate we are reconstructing the low-frequency changes better than the higher-frequency ones. We are suspicious of the apparently excellent reconstruction for regions east of the Mississippi River. While we do obtain some verification on independent data, it is less marked than for the West. On the other hand, a check against Landsberg's data for Philadelphia (Landsberg, 1968) shows high correlation ($r^2 = 0.61$) for the calibration period 1901-1962 but no significant correlation for the independent record for the nineteenth century. More verification tests must be obtained using eastern records before we will claim that our reconstructions for that region are valid.
### TABLE VIII

Correlations Squared (Percent Variance × $10^{-2}$) for Reconstructions of Winter Temperature Using Model 7t15b15i and Actual Data for 1901-1962

<table>
<thead>
<tr>
<th>Region Name</th>
<th>No. of Stations</th>
<th>Correlation Squared</th>
<th>Average of Individual Stations</th>
<th>Unfiltered</th>
<th>Low-Pass Filter</th>
<th>High-Pass Filter</th>
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<tr>
<td>Pacific Northwest</td>
<td>5</td>
<td>0.327</td>
<td>0.322</td>
<td>0.496</td>
<td>0.298</td>
<td>0.480</td>
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<tr>
<td>California</td>
<td>8</td>
<td>0.419</td>
<td>0.490</td>
<td>0.575</td>
<td>0.394</td>
<td>0.476</td>
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<tr>
<td>Great Basin</td>
<td>7</td>
<td>0.413</td>
<td>0.476</td>
<td>0.591</td>
<td>0.396</td>
<td>0.494</td>
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<tr>
<td>Southwestern Desert</td>
<td>6</td>
<td>0.400</td>
<td>0.452</td>
<td>0.722</td>
<td>0.497</td>
<td>0.235</td>
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<tr>
<td>Northern Plains</td>
<td>7</td>
<td>0.252</td>
<td>0.274</td>
<td>0.461</td>
<td>0.461</td>
<td>0.176</td>
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<tr>
<td>Southern Plains and Texas Coast</td>
<td>8</td>
<td>0.243</td>
<td>0.254</td>
<td>0.497</td>
<td>0.497</td>
<td>0.050</td>
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<tr>
<td>Great Lakes, Upper Mississippi and Ohio Valleys</td>
<td>11</td>
<td>0.408</td>
<td>0.457</td>
<td>0.792</td>
<td>0.379</td>
<td>0.399</td>
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<tr>
<td>Lower Mississippi, Gulf Coast</td>
<td>9</td>
<td>0.418</td>
<td>0.471</td>
<td>0.776</td>
<td>0.369</td>
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<tr>
<td>Atlantic Coast</td>
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<td>0.491</td>
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These data can be examined to study the frequency and duration of droughts in different areas of the United States in order to provide a basis for statistically predicting how long the existing conditions are likely to continue and how often they are likely to occur in the future. As far as we know at the present time, no other research group can produce information anywhere matching this capability. We believe it is worth the effort to continue with the careful analysis and documentation as described in the previous pages, and we also believe that if we are allowed to pursue the work to its completion, we will have a most unique set of data which will serve many purposes and which could help solve climatic problems important to planning our country's future.
V. PERSONNEL WORKING ON GRANT FUNDS

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*Partially paid on state funds.
VI. PUBLICATIONS RESULTING FROM THIS GRANT


*Acknowledgements (including the National Science Foundation) inadvertently left out at some stage of the editing process.
VII. PAPERS IN PREPARATION


Stevens, D. W. In preparation. User's manual for Program DTYPE. Laboratory of Tree-Ring Research, University of Arizona, Tucson.

Stevens, D. W. In preparation. User's manual for Program MERGE. Laboratory of Tree-Ring Research, University of Arizona, Tucson.

Stevens, D. W. In preparation. User's manual for Program PRMAP. Laboratory of Tree-Ring Research, University of Arizona, Tucson.

Stevens, D. W. In preparation. User's manual for Programs PPLOT and CCOMP. Laboratory of Tree-Ring Research, University of Arizona, Tucson.

Stevens, D. W. In preparation. User's manual for Programs PRTIME and CLTIME. Laboratory of Tree-Ring Research, University of Arizona, Tucson.

Stevens, D. W. In preparation. User's manual for Programs XFER and SIMUL. Laboratory of Tree-Ring Research, University of Arizona, Tucson.

Winter, C. L. In preparation. Documentation for Program ANOVA. Laboratory of Tree-Ring Research, University of Arizona, Tucson.

VIII. LITERATURE CITED


Fritts, H. C. 1976a. Applied research reconstructing past climate of the Northern Hemisphere by the use of tree rings. Progress report to the National Science Foundation, Grant No. ATM75-17034. Reporting period: October 1, 1975-June 1, 1976. 46 pp.


Literature Cited, cont.


APPENDIX 1

International Tree-Ring Data Bank Newsletter

127-137
FROM THE CHAIRMAN’S DESK

In 1977 we dendrochronologists find ourselves becoming a highly relevant group of environmental scientists. However, instead of seeking the many common elements and unique opportunities and methods that bring us together, we sometimes stress our individual differences separating ourselves into small, ineffectual units. The sharpest division may be between the archaeological and historical daters and those interested in reconstructing past environments. There also seem to be distinct national groups and methodological schools. In addition, we sometimes identify one another more with subdivisions such as dendroarchaeology, dendroclimatology, dendrohydrology, dendrogeomorphology, and xylodendrochronology than with the mother field, dendrochronology.

I would like to assert my conviction that the many elements we all have in common far outweigh our differences. What is most important is that we are all a part of one field, dendrochronology, the use of tree-ring variations to date the annual growth layers. I am also convinced that when we focus on the divisions among us, it is often counterproductive and perhaps even detrimental to the continued growth of the science. While honest differences will and should always exist among us, I believe the time has come for us to begin identifying the many common principles, concepts, and practices that can unite us and which will increase the productivity and usefulness of our chosen field.

It is the hope of the International Tree-Ring Data Bank Committee that the Data Bank can serve as one of the unifying forces among dendrochronologists throughout the world. In order to assure its international scope, the membership of the guiding committee is composed of scientists in four different countries. The organization of the Data Bank was structured to insure its independence from both the Tree-Ring Society and the Laboratory of Tree-Ring Research, and a modest amount of funding has been obtained from United States sources (without obligating the contributors) to enable us to take the first steps toward the fulfillment of our goals. Thus, it is especially important and urgent during this early developmental period that all potential contributors and users of the Data Bank participate with us in its development. It is with this intent in mind that we have prepared this Newsletter. We urgently need assistance from all parts of the dendrochronological community, not only in the form of data contributions, but also as ideas on how the Data Bank can best serve the science while giving the contributors the necessary protection and the users the information they need.

We are archiving the dated ring-width measurements. Shouldn't we be making some kind of universal standardization at least for the better data sets?

(Continued on page 2)
At the moment, our greatest efforts are focused upon getting the individual ring data and the appropriate site information. After a careful review of the progress to date, it appeared that our original requirements of at least 10 trees per site and two replications per tree were too limiting at this point in time. Very few contributions were being made simply because they did not meet all the desired specifications. Although we still hope to obtain samples of this quality, we have initiated another class of data allowing shorter chronologies based upon smaller numbers of trees. This class (which may be temporary) will enable us to start with the materials already collected. Each set of data will be assigned to the appropriate class, and we hope that in the future more and more contributions will fall in the higher quality category. Sometime in the future when we are all collecting the large samples of high-quality data, we might wish to discontinue accepting new materials in this second class. The matter will be discussed at the next meeting of the Data Bank Committee.

However, it is important that we consider carefully what our future directions should be. I plan to call an open meeting of the International Data Bank Committee at the INQUA meeting in Birmingham in August, 1977, to discuss these matters, a meeting to which you are all invited. It would be nice if there were some opportunity for discussion at the Dendrochronology Symposium in Greenwich, but at present, nothing has been scheduled for that event. However, I will be there to meet and discuss matters with those interested. I also invite you to express your wishes and needs in writing. In the next Newsletter we will attempt to include any relevant comments we receive and we shall attempt to cover the points at the meeting in hopes of starting a genuine dialogue among us all. If we can achieve some measure of communication and understanding, I firmly believe we will find that we have much to learn from one another and there is much more to unite us than to divide us.

I would also like to personally thank all of you who have made contributions and ask for your continued support in terms of any new valid and well-dated materials. The present chronology material is a small but very important and significant start. Because of your recent response, we are in a strong position to ask for continued funding. Now if we can establish a useful, growing dialogue, a spirit of cooperation and unity among us, I am confident that we can move ahead in our various sub-disciplines, united and strengthened by the fact that we are all dendrochronologists sharing our basic data, the synchrony in growth rings, to solve a variety of problems around the world.

--Harold C. Fritts

CALENDAR

JULY 11-14, 1977: INTERNATIONAL SYMPOSIUM ON DENDROCHRONOLOGY IN NORTHERN EUROPE; LONDON, ENGLAND

AUGUST 16-24, 1977: TENTH INQUA CONGRESS, UNIVERSITY OF BIRMINGHAM, ENGLAND

AUTUMN, 1977: VOLUME 2, NUMBER 2, ITRDB NEWSLETTER

UPCOMING EVENTS

Two meetings of particular interest to scientists engaged in dendrochronological research will take place during the summer of 1977. The first is the International Symposium on Dendrochronology in Northern Europe to be held at the National Maritime Museum, Greenwich, London from July 11 to July 14, 1977. This will be the first dendrochronological regional conference in Europe. As

(Continued on page 3)
stated in the advance circular: "The purpose is to focus attention on progress in the temperate (transalpine) part of Europe. The symposium should be of interest to laymen as well as those engaged professionally in the field."

Further information is available from:
The Organizing Secretary,
Symposium on Dendrochronology in Northern Europe
National Maritime Museum,
Greenwich, London
SE10 9NF, ENGLAND

The second meeting will take place during the Tenth INQUA Congress at the University of Birmingham, England, from August 16-24, 1977. At this time special symposia on dendrochronology and paleoclimatology are planned for all interested participants. There will be discussions about the International Tree-Ring Data Bank, and the Committee will hold a planning session to which all interested persons are invited. This will be an opportunity to raise questions about the Data Bank as well as to express opinions or to make contributions. Site Information Sheets and other data regarding the requirements for acceptance of materials into the Data Bank will also be available at that time.

SCHWEINGRUBER GIVES 12 SITES

Fritz H. Schweingruber of the Swiss Forest Research Institute, Birmensdorf, Switzerland, visited H. C. Fritts at the Laboratory of Tree-Ring Research from August 20 to September 30, 1976. The purpose of his visit was to standardize his tree-ring materials from Switzerland and to use them to reconstruct climate. Materials provided by Schweingruber included tree-ring data from six locations consisting of 37 subsites (with differences in elevation and species). The five parameters measured on each ring were earlywood, latewood, minimum density, maximum density, and total ring width. The climatic data were from six weather stations. A total of 185 different chronologies were processed, and numerous response functions were obtained. The climatic reconstructions were highly significant for four stations using canonical analysis and six tree-ring sites. Maximum density was by far the best predictor of climate, but the best results were obtained by using five parameters to reconstruct climate. Schweingruber contributed 12 of the best sites used in the study to the International Tree-Ring Data Bank. This represents the first contribution of data other than ring width to the Data Bank.
SITE INFORMATION SHEET REVISED

In an attempt to streamline the procedures for submitting materials to the Data Bank, the Site Information Sheet originally prepared in 1974 has been revised and simplified. The amount of information which is now required for each site has been reduced to include only the most essential information, and the form itself has been reorganized. It is hoped that this will encourage more scientists to submit their data and will also speed up the processing of the materials once they are received by the Data Bank. A copy of the revised Site Information Sheet is enclosed, and additional copies may be obtained by writing:

Manager, International Tree-Ring Data Bank
Laboratory of Tree-Ring Research
University of Arizona
Tucson, Arizona 85721
U.S.A.

Photocopies of the enclosed Site Information Sheet may also be used to submit data.

Submissions for the Autumn issue of the Newsletter must be received by the Editor (address on page 10) by August 31, 1977.

BERND BECKER VISITS TREE-RING LABORATORY

Bernd Becker of the Universität Hohenheim, Stuttgart, Federal Republic of Germany, visited the Laboratory of Tree-Ring Research in Tucson, Arizona in July, 1976. While at the Laboratory, Dr. Becker, who is a member of the International Tree-Ring Data Bank Committee, conferred with Harold C. Fritts, Chairman of the ITRDB Committee, regarding revision and simplification of the current policies governing the Data Bank. Dr. Becker visited the Laboratory following the Ninth International Radiocarbon Conference held in Los Angeles and San Diego, California. (For further information on the revised procedures regarding acceptance of materials in the International Data Bank, see Page 4, column 2.)

La version revisitée du questionnaire de la localité est disponible maintenant en français sur demande au Tree-Ring Laboratory.

DATA ENTRY REQUIREMENTS AMENDED

A careful review of both the current Data Bank holdings and numerous potential contributions indicated that a new classification of data was essential, at least for the time being, to enable the Data Bank to get started. Therefore, with this issue of the Newsletter, the International Tree-Ring Data Bank announces a new classification of data which will allow for smaller samples with single replicated ring width (or other parameters) from three or more trees and with total lengths of less than 100 years. Minimum requirements for acceptance of materials into this classification (Class B) are: (1) original ring-width measurements must be included with each contribution; (2) there must be a minimum of three trees per species and site (although larger samples are encouraged); (3) all materials must be absolutely crossdated; and (4) a completed Site Information Sheet (including signature) must accompany each site.

It should be emphasized, however, that the original requirements for the acceptance of materials in Class A as established at the International Workshop in Dendroclimatology in 1974 have not been discontinued, and scientists whose materials meet these standards are urged to submit them. Additional requirements for materials to be entered into this classification are: (1) ring measurements must have a minimum length of 100 years; and (2) there must be a minimum number of 10 trees per species and site with two measured radii per tree. Since the decision to initiate a new class was made by the Chairman, the entire committee will have to decide how long to continue this new class and whether contributors of Class B data will have access to Class A material.

(Continued on Page 5)
At this time, we have not arrived at a policy regarding users. For the present, only those persons submitting original ring materials will be able to request other materials from the Data Bank. We will have to decide within the year how requests for data will be met and how the costs will be handled. Send ideas, inquiries, and submissions to:

Manager, International Tree-Ring Data Bank
Laboratory of Tree-Ring Research
University of Arizona
Tucson, Arizona 85721
U.S.A.

KAREN BABCOCK RESIGNS AS ITRDB MANAGER

Mrs. Karen Babcock McDougall resigned her position as Manager of the International Tree-Ring Data Bank effective October 1, 1975. Her resignation was submitted prior to her marriage in September to Capt. Charles McDougall and their subsequent move to Maryland where Capt. McDougall is stationed. Mrs. McDougall played an important role in the formation of the International Data Bank, and her resignation was reluctantly accepted by Harold C. Fritts, Chairman of the ITRDB Committee. Mrs. McDougall's position as Data Bank Manager has been filled by Mrs. Judith A. Sherwood of Tucson, Arizona.

10 WEST GERMAN CHRONOLOGIES DONATED BY BURGHART SCHMIDT

Burghart Schmidt of the University of Cologne, Federal Republic of Germany, visited the Laboratory of Tree-Ring Research at Tucson, Arizona, during October, 1975, to work with H. C. Fritts. The visit ended with a successful attempt to reconstruct climate using European tree-ring materials. For this project, 11 tree-ring chronologies were used to reconstruct temperature and precipitation data selected from 12 weather stations. Ten of the chronologies developed by Schmidt and others have now been entered into the International Tree-Ring Data Bank along with 14 response functions obtained for them. The results of this collaboration are to be part of Schmidt's Ph.D. thesis which is under the direction of Dieter Eckstein, Hamburg.

FACTS AND FIGURES

A brief analysis of the holdings of the Data Bank indicates its worldwide acceptance as evidenced by the following facts and figures:

- Total number of chronologies contributed: 244
- Total number of sites contributed (including subsites): 196
- Total number of individual contributors: 20
- Total number of institutional contributors: 1
- Total number of countries represented: 13

In addition, the International Tree-Ring Data Bank Newsletter is read by scientists in 18 countries speaking 14 different languages. It is gratifying to know that this is truly an international endeavor!

Judi Sherwood (left), Data Bank Manager, and Linda Drew (right), Technical Assistant, discuss the entry of the newest contributions to the Data Bank.
CURRENT HOLDINGS OF THE ITRDB
AS OF MARCH 1, 1977

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# INTERNATIONAL TREE-RING DATA BANK: REVISED SITE INFORMATION SHEET

## REQUIRED INFORMATION

1. **NAME OF SITE**

2. **COUNTRY**

   State or Province

   Subdivision

3. **NAME OF SUBMITTOR**

   Last Name

   First Name

   Initial

   ADDRESS OF SUBMITTOR

   Institution

   Country

4. **NAME(S) OF COLLECTOR(S)**

   ADDRESS(ES) OF COLLECTOR(S), if different from 3.

5. **DATE COLLECTED**

   Year

   Month

   Day

6. **SOURCE OF COLLECTED MATERIAL**

   1) Living trees 2) Historical 3) Archaeological

   4) Geological 5) Other

7. **ELEVATION (altitude)**

   meters

8. **LATITUDE**

   Degrees

   Minutes

   Seconds

   1) North 2) South

9. **LONGITUDE**

   Degrees

   Minutes

   Seconds

   1) East 2) West

10. **COLLECTED GENUS**

    SPECIES

11. **NUMBER OF TREES**

    TOTAL NUMBER OF RADII MEASURED

    NUMBER OF RADII PER TREE

12. **TYPE OF MEASUREMENT**

    1) Total ring width 2) Earlywood width only 3) Latewood width only

    4) Both earlywood and latewood 5) Density measurement 6) Other

13. **UNIT OF MEASUREMENT OF BASIC DATA**

    1) 100ths mm 2) 10ths mm 3) 100ths inch

    4) 10ths inch 5) Other

14. **BEGINNING YEAR OF CHRONOLOGY**

    ENDING YEAR

15. **SUBMITTOR’S CLASSIFICATION OF DATA**

    1) Available to all Data Bank users 2) Available by permission of submittor only

I acknowledge that all materials within the site do crossdate and that actual measurements (not derived indices) have been submitted.

**SIGNATURE OF SUBMITTOR**

**DATE** 9/76
CARD HANDLING PROCEDURES
FOR THE
INTERNATIONAL TREE-RING DATA BANK

1. Data should be submitted in the standard format used by the International
   Tree-Ring Data Bank, if possible. Copies of this format are available at
   no charge by writing:
   Manager, International Tree-Ring Data Bank
   Laboratory of Tree-Ring Research
   University of Arizona
   Tucson, Arizona 85721
   U. S. A.

   However, other formats can be accepted provided that they are adequately
documented.

2. Each card should be identified according to site, tree, radius, and date
   of the first ring-width value on the card.

3. If each card is not identified individually, please include a listing of
   the deck along with the cards when they are mailed.

4. It is a good idea to draw a diagonal line in ink from corner to corner
   across the top edge of the deck. This makes it easier to see if a card
   is out of sequence.

5. Please send all cards for each site at one time and include the Site
   Information Sheet with the cards, if possible.

6. Data may be submitted on magnetic tape also (preferably 9-track). If
   a tape is submitted, it must be written so that it can be easily read on
   a CDC computer. This would include character mode (not binary), fixed
   length records, and constant size blocking. A detailed description of how
   the tape was written and the actual contents must accompany the tape.
PRESENT HOLDINGS

Since the Newsletter was last published in 1975, the Data Bank has received many new contributions. In addition to the contributions by Schmidt (see page 5, column 1) and Schweingruber (see page 3, column 1), the following materials have been received for European sites: A site in Austria and a site in Switzerland were the joint contribution of Valmore C. LaMarche, Jr., and Harold C. Fritts, both of the Laboratory of Tree-Ring Research. Data from Northern Ireland have been received from Jon Pilcher and Michael Baillie, both of the Queen's University, Belfast. Bernd Becker of the Universität Hohenheim, Stuttgart, has contributed 10 sites from the Federal Republic of Germany, 5 sites from Czechoslovakia, and 5 sites from Italy. Dieter Eckstein of the Universität Hamburg is submitting three sites in the Federal Republic of Germany. Two Canadian sites were contributed by Martha A. Wiseman of the Laboratory of Tree-Ring Research. Several sites from the United States were also received this past year. Among them were 10 sites in Idaho and Washington collected by Linda B. Brubaker of the University of Washington, and an Alaskan site donated by Harold C. Fritts. Arthur V. Douglas of the University of Nebraska contributed ring widths from California, and Charles W. Stockton of the Laboratory of Tree-Ring Research donated a site in New Mexico. Numerous sites in the American Southwest were contributed by W. J. Robinson, also of the Laboratory of Tree-Ring Research. A collection of 102 sites in western North America (including sites in Canada, Mexico, and the United States) was submitted by the Laboratory of Tree-Ring Research.

The year 1976 also saw the official entry of a number of sites which had been tentatively submitted earlier. Two sites in Switzerland contributed by André Munaut of the University of Louvain, Belgium, were among those entered into the Data Bank. Materials from France submitted by Françoise Serre, of the Université Aix-Marseille, France, were also entered. B. A. Kolchin's data from an archaeological site at Novgorod, U. S. S. R., were also processed and added to the Data Bank. In addition, the processing was completed for three sites in Sweden donated by Thomas Harlan of the Laboratory of Tree-Ring Research and Bengt Jonsson of the Royal College of Forestry, Stockholm, and for two other sites in Sweden made available by Harlan. Also, Edward Feliksik and Zdzisław Bednarz, both of the Academy of Agriculture, Kraków, Poland, each completed the entry of a new site in Poland.

For a list of current holdings, which are available to Data Bank members only, see pages 6 and 7.

INTERNATIONAL TREE-RING DATA BANK

Published under the auspices of the International Tree-Ring Data Bank with international headquarters at the Laboratory of Tree-Ring Research, University of Arizona, Tucson, Arizona, U. S. A. The Data Bank receives partial financial support from the National Science Foundation, Grant No. ATM75-17034. The ITRDB Newsletter is circulated free of charge upon request. The editor reserves the right to select, delete, and correct copy submitted for publication. Address all letters and submissions to: Editor, ITRDB Newsletter at the above address.
APPENDIX 2

Press Release Issued Jointly by
Harold C. Fritts
and
the National Science Foundation
February 28, 1977
ARIZONA SCIENTISTS USE TREE RINGS TO RECONSTRUCT
300 YEARS OF NORTH AMERICA'S CLIMATE

The frigid winter and drought that have stricken parts of the United States this year would not have surprised weather watchers if they had studied tree rings, according to University of Arizona scientists who have used ring widths to reconstruct more than 300 years of climate in North America.

Dr. Harold C. Fritts, who heads the group at the university's Laboratory of Tree-Ring Research, also said statistics based on tree-ring analysis indicate the northeast should expect cold winters like the present one to occur almost half of the time.

Dr. Fritts' team at the laboratory, including meteorologists Dr. Terence J. Blasing and G. Robert Lofgren, are studying past climates by analyzing widths of annual tree rings from nearly 1,000 trees in western North America. Their research is funded by the National Science Foundation's Climate Dynamics Program.

-morer
"The annual ring widths from the sample trees are measures of climatic factors as they have varied over all four seasons of the year," Dr. Fritts said. "When many trees are sampled from a variety of sites over a wide geographic area, the ring widths contain a wealth of information on the environment that, in turn, is highly correlated with the regional climate."

With the help of computers, the scientists not only relate the ring widths to factors affecting the growth of the trees, but they also use the ring widths to reconstruct patterns of past climate over North America. The computer compares climate to ring widths to provide a scale that is analogous to the markings on a thermometer or rain gauge. This scale then is used to convert ring-width measurements into estimates of corresponding temperature or precipitation for years before climatic records were kept.

In this way, Dr. Fritts and his group have reconstructed climatic variations back to 1600 A.D. Ring widths throughout the Rocky Mountains and Colorado Plateau were generally narrower in the 17th, 18th and 19th centuries than those since 1900. This pattern of narrow rings is identified with winters that were dry in the West and cold in the North and East -- much like the current winter, Dr. Fritts said.

They also have identified several general types of climatic patterns common to 20th century winters. Two of the patterns with warm weather throughout eastern United States were reconstructed 28 per cent less frequently in the earlier centuries, while two patterns involving cold conditions either in the North or East were reconstructed to have occurred 21 per cent more frequently.

Based on their work using 300 years of reconstructed climate before 1900, the scientists have concluded that the average winter temperatures for the United States were significantly colder for much of the East and North and slightly warmer in the Southwest between 1600 and 1899 than during this century.

"If the past is the key to the future," Dr. Fritts said, "and if we can use the climate reconstructed for 1601 to 1899 and recorded for 1900 to 1970 to estimate the normals to expect, then we should plan on 15 winters per century with cold in the East and Southeast and dry and mild in the Southwest.

"On top of this, we can expect approximately 32 additional winters per century to be colder than average throughout the north central and northeastern United States. Therefore, statistically speaking, the calculations indicate cold winters of these two types can occur 47 per cent of the time, or almost one out of two years in the future."

In addition, Dr. Fritts said, 25 out of 100 years can be expected to be warmer than average in the East.